PRODUCT ENGINEERING

JULY, 1948

HIGH SPEED
CAM OPERATED LOOM

IN THIS ISSUE—Designing With Light Alloys + Brittle Coating Data + Backlash in Gears + Non-Destructive Methods for Testing Materials + Industrial Solenoids

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Why Some Men

STAY MARRIED TO WRENCHES

Improved performance and minimum bulk make these nickel alloy steel Snap-on ratchet wrenches favorites throughout industry.

PAWL BEING ASSEMBLED IN RATCHET HEAD. Use of nickel alloy steel and extraordinary care in machining these parts, assure free working action at all times.

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Highlights

In this summary of technical developments, space restrictions do not allow giving complete details. Further information relating to any item can be obtained by writing to the Editor of Product Engineering.

PLASTICS AND RUBBER

If and when metals used in die-casting become relatively unavailable, plastics will have real opportunities. ERP, UMT and Air Force expansion may combine to convert the possibility to a reality. Every application must be considered separately to keep from giving plastics a bad name.

Fiberglas blankets are now used to absorb sound waves from self-contained air conditioning units, before noise gets to ducting...Special 10 ft glass fiber wing panel sections are being tested on a Douglas C-54 to evaluate protection against electrical interference with radar equipment mounted within the panel.

HIGH TEMPERATURE ELECTRICAL INSULATION is simplified by new Fiberglas-reinforced industrial laminate. With resistance to high temperatures and long exposure, this material is suited for use as slot sticks and armature end laminations.

A new plastic, thermoplastic resins blended with synthetic rubber, can be molded in any color or shape and with various degrees of hardness. Made by U. S. Rubber Co., the plastic has strength of wood but will not split under blows from an ax.

If you want to load your baby carriage bearings with sand and drive it 353 miles or go 1,190 miles with axles vertical, try nylon bearings and see no bearing wear and little axle wear. Good for machine bearings up to 325 F, using lub oil or water. No oil spots on fabrics if used on textile machines with water.

PAPER OR CLOTH, impregnated and surfaced with a polyester thermosetting resin, forms base for plastic now produced in 34 different colors and patterns, with gloss or satin finish. Burn-proof types also.

POLYSTYRENE is replacing high grade tin alloys for use in number wheels and pinions for counting instruments. "Plastics" (British) mentions that polystyrene costs less per pound and produces five times as many castings per pound.

OXY-HYDROGEN FLAME, rapidly passed over sawed opaque edges or acrylic rods quickly makes them clear and free from saw marks. Oxy-hydrogen is used instead of acetylene so no carbon residue will form. Method has been used for acrylics and polyethylene but other thermoplastic types either distort or craze.

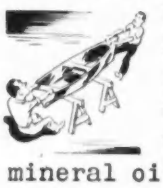
Not yet commercially available, new characteristics are being given to nylon by du Pont chemists. One type is water-white transparent; another has higher melting point, greater stiffness and lower water absorption. Ordinary 66 nylon has 25% elongation but a new one has several hundred percent elongation.

NYLON FABRIC AND RUBBER have been combined to make an improved pressure regulator diaphragm. It replaces sheepskin and cotton duck and has greater flexibility, high bursting strength, good sensitivity and is lighter in weight.

Mechanical sealing, packing and gasketing materials now being made of Hycar-impregnated felt. Hycar surface holds oil in, up to 400% of its weight, and seals dirt out.

NONFERROUS METALS

Hulls for aluminum boats that are 12 ft long have been drawn in one piece from 0.064 in. aluminum, SAE 281. Hulls are 55 in. wide, and 22 in. deep. A 1,700 ton double acting mechanical press was used with a 40% paraffin compounded mineral oil lubricant. The lubricant was applied to the top surface of the blank



Continued on Page

Engineering To Assure Peace

MANY CONFLICTING THOUGHTS and emotions have arisen because of the confused world conditions. There are some who, like Henry Wallace, believe that a conciliatory attitude toward those who seem to be bent on trouble would solve everything. Many people, abhoring conflict or anything that might lead to war, are fearful lest the building of armaments will create a desire to put them to use. Another segment of the people look with strong distaste on the prospect of again going through a period of materials shortages with possibly also rationing and price control. All of these attitudes are dictates of the emotions rather than rationalization.

History and the cold facts of human behavior clearly indicate that the rearmament program offers the only possible solution for the peaceful settlement of present international problems. Men in power despise weaklings and sneer at them. In all the centuries of recorded history, no weak nation has ever been respected. There can be no leadership without the respect of those to be lead. The voice of a weakling in the councils of the mighty is never taken seriously.

National might is measured by the quantity and quality of the implements of war that the country has ready. It did not worry Hitler or Hirohito that the United States of America had the scientific ability and industrial capacity to develop and produce the finest weapons in abundance. They did know that it would require at least three years for the production lines to start rolling, and it did. According to their reckonings the conflict would be over by that time. Hence they felt safe to launch their wars.

The present program aims to develop and build limited quantities of the most ultra modern weapons achievable. The degree of success of that undertaking will depend almost entirely on the scientists and engineers who develop the war equipment. Every designer, regardless of his rank or title, will be an important contributor to future peace and security. "For the want of a nail the battle was lost", is an old saying but highly expressive. The most humble detail in the design of a highly complicated weapon may spell its success or failure.

Again the design engineers have been put to the task of developing armaments. We hope that this time the objective will prove to have been to avoid war rather than to win a war. But regardless of what the future may bring, the immediate task is to design so well that it will place us decades ahead of all other countries, instead of years behind.

G. F. Jordenholt

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1

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2

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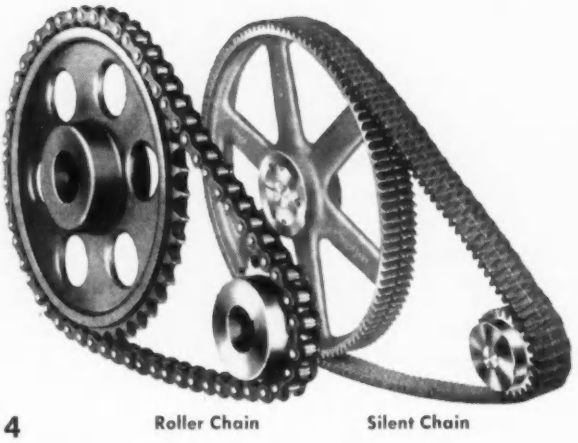

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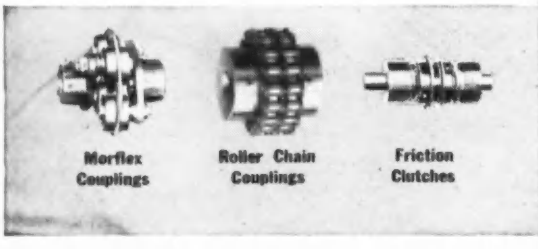

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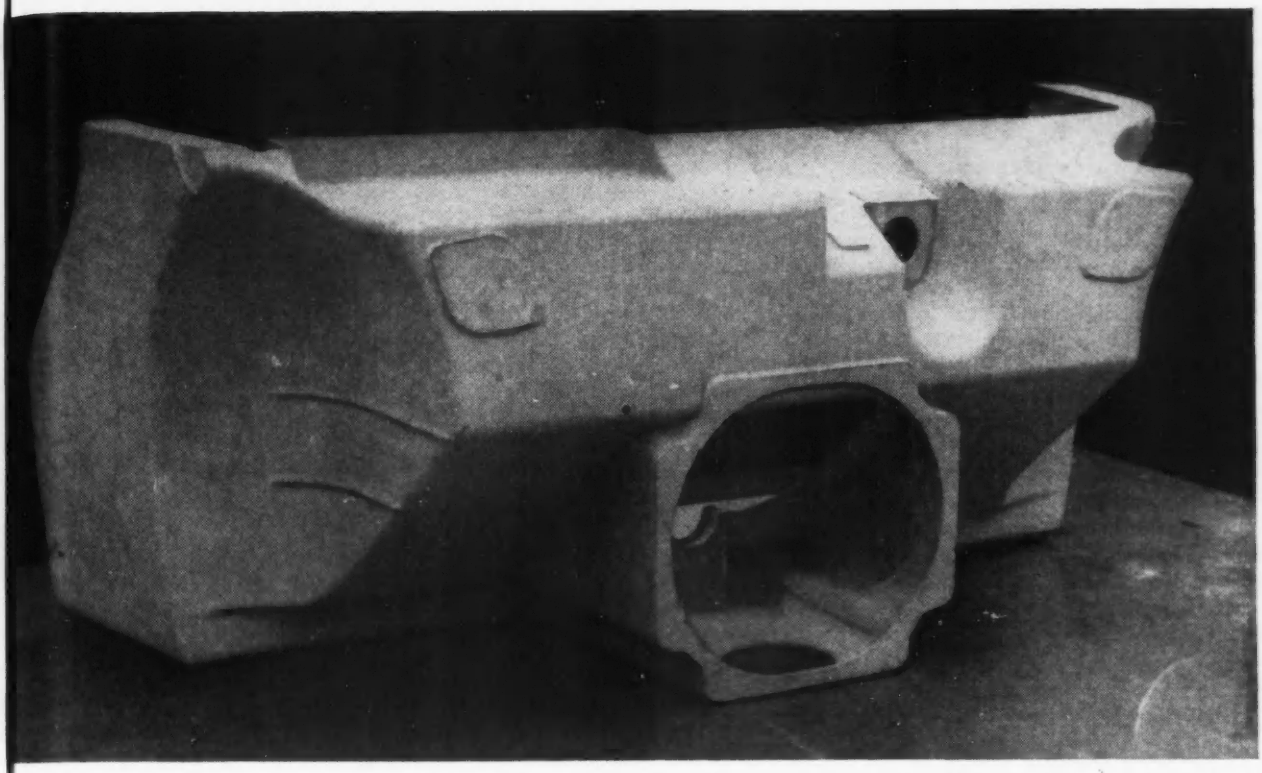

HT ALLOY CASTINGS are suggested to replace the conventional steel chassis or stamped body-shell. This lower dashboard ing is the principal structural member of the car. The casting offers greater structural rigidity and substantial weight reduction.

Light Alloys Need New Design Concepts

he simple substitution of a light alloy for steel a good design actice? The author, a leading European automotive engineer d inventor of the Tracta universal joint, holds that substitution oduces only an approximation of the possibilities. He calls for complete break with traditional design when using light alloys. s comments are presented just as they have been written, in belief that readers will enjoy the inimitable Gallic style.

J. A. GREGOIRE
President of Sté. An. des Automobiles Tracta
President of Sté. des Brevets J. A. Grégoire

EIGHT REDUCTION in automotive nsport has always been of prime im- rtance in Europe. One ton of ight reduction on a bus or truck ables transportation at no added pense of a ton of passengers or ods. The American automobile in- stry seems on the other hand not to e realized the advantage of light- ng passenger cars.

The European regards with stupor, the immense avenues of cities such as Los Angeles, thousands of cars following each other in line, each weighing three to four thousand pounds, powered by 80 to 150 hp motors, usually carrying a single passenger at thirty miles an hour. Yet there is no doubt that we could keep equal comfort and performance and save 40 percent of the car's weight and 40 percent of the fuel consumption. In the near future American builders will have to tackle this problem, which for the past ten years has been seriously studied in Europe. That lightness is the aristocracy of mechanical technique is equally true on both sides of the Atlantic.

In the search for lightness, while keeping steel as the basic material, the heavy chassis in thick U-formed sheet has been transformed into the tubular caisson in thin sheet. The body, first in wood and sheet steel, has been executed entirely in steel. Then this body, instead of being bolted to the tubular side-members, has ended by being welded to these parts. Finally, the chassis has disappeared, and it is the lower part of the all-steel body that now fulfills the mechanical role of the frame. One has the "coque" [Editor's note: literal translation, "shell"], or chassis-body, a logical and seductive solution, though not lacking in inconveniences.

Thus having obtained from steel the maximum lightening effect, the engineer has turned toward the light alloys because of their low specific weight. Two schools of use have now developed.

The doctrine of the first consists in substituting these new alloys for steel, using the same technical solutions and allowing for the new modulus of elasticity, mechanical characteristics, formability and weldability.

The second school reconsiders the problem from its basic elements. In-

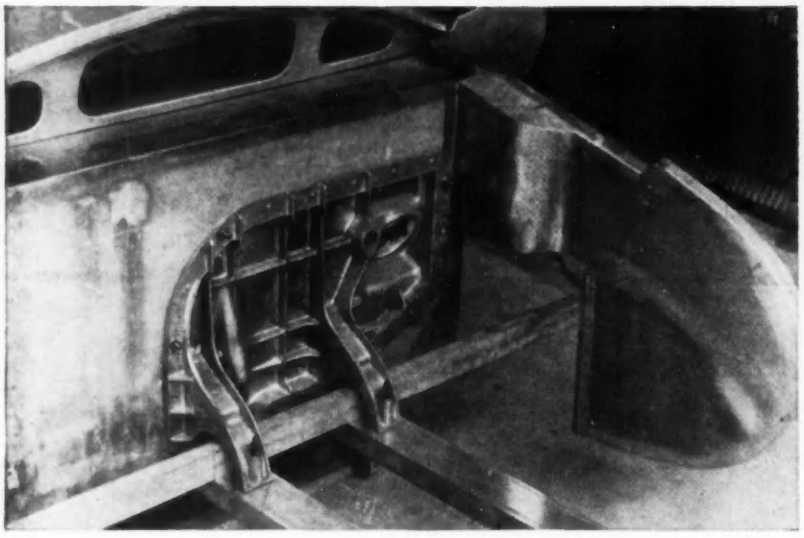

Fig. 1—One problem in the shell design is to spread concentrated loads over a large panel area. This casting supports the motor and the forward suspension.

Fig. 2—Dashboard of the Adler. Although s
plified compared to others, it still has 13 pa

stead of adopting a technique used for another material and which, for this reason, has little chance of being the most advantageous one, it seeks new techniques which take account of the "mentality" of the new material. By mentality is meant the good points, which for light alloys are: Lightness, castability, conductiveness; and the defects, which are the low modulus of elasticity and the difficulties of deep stamping and welding. This second school doesn't transpose, it innovates.

We shall examine manifestations of these two schools and shall try to determine on which side lies the truth.

Transposition

The problem of transposing from a steel material to a light alloy material is relatively simple. The fact of starting from an already proved structure frees the engineer from the always arbitrary determination of the stresses to which the material is submitted. The whole problem then is to dimension parts so that construction in a different material gives the same resistance.

Characteristics of primary importance include rigidity to flexion and torsion, and also the coefficient of safety to apply to both static and dynamic constraints. The dimensions of the shape are dictated by the most imperative of the relative conditions about the principal axes, xx' and yy'. The first formula is for rigidity, the second for the value of flexional constraints. Respectively, E and E', t and t' are the moduli of elasticity and the admissible work rate (in practice, the fatigue ultimate strength) in the old and new materials; v and v' represent the distance of the most loaded fiber from the neutral fiber; and I and I' moments of inertia in the old and new structures.

$$\frac{I_{xx'}}{I'_{xx'}} = \frac{E'}{E} \qquad \frac{I_{yy'}}{I'_{yy'}} = \frac{E'}{E} \qquad (1)$$

and

$$\frac{I_{xx'}/v}{I'_{xx'}/v'} = \frac{t'}{t} \qquad \frac{I_{yy'}/v}{I'_{yy'}/v'} = \frac{t'}{t} \qquad (2)$$

The first group of relations necessitates for light alloys, moments of inertia three times as high; the moduli being in inverse relation to the fatigue limit, or approximately in the ratio of two to one.

Where it is a matter of making a new structure of light alloys, the engineer would do well to draw up a first design in steel. Then, following the preceding rules, he can convert.

At first sight there seems no reason why one should not use as thin a sheet as possible. Formed into the proper shape, this would possess a reduced unit weight and a high moment of inertia. Calculation shows that if one increases homothetically (similarly) the exterior dimensions for a certain shape while reducing the thickness in such fashion that the weight per running foot remains constant, the moment of inertia increases approximately as the square of the homothetic ratio, K (the ratio of the new to the old dimensions). Also, I/v increases in the same proportions. The deflection decreases as K^2 and the fatigue of the metal as K in these conditions.

But one is limited in this direction by the danger of the shape buckling. Few structural elements of the automobile work as columns under pure compression; buckling of the whole is thus little to be feared. On the other hand, the risk of local buckling leads to avoidance of overly reduced thi
nesses in tubular shapes. Resistance
local deformations is tied to the pr
uct, EI, of the elementary section co
sidered. This resistance increa
therefore, directly as the modulus a
as the cube of the sheet's thickness
also varies in inverse relation to
radius of curve.

When transposing an establish
steel body into light alloys, one shou
theoretically, increase the thickne
in the panels in proportion to the cu
root of the moduli, that is, multip
them by 1.45. With elements su
ciently curved, a boost of 25 percen
ample. Thus, one can pass from st
sheet of 0.95 mm to sheets of 3 p
cent Mg alloy of 1.20 mm thickne
When seeking maximum lightness
hollow shapes, one should avoid f
surfaces as much as possible in fav
of curved forms with a radius of cur
ture such that the danger of lo
buckling is forestalled. These radii
curvature must allow stamping a
also tolerate normally any acciden
deformations.

Nonheat-treated alloys possessi
satisfactory mechanical characteris
in the reheated state, such as 3 and
percent Mg alloys, can be used. Th
alloys can be spot-welded, or weld
with oxy-acetylene, with atomic h
drogen or by the Heliarc process.

Example of Transposition: The Mathis-Andreau Au

This car of the box-coque type co
sists of a box frame base to which a
fixed the lateral panels and the das
board. The whole of the structure
strengthened by tubular shapes of hi
inertia. Sections of the different holl
shapes forming the ribs of the b
frame and other details are describ

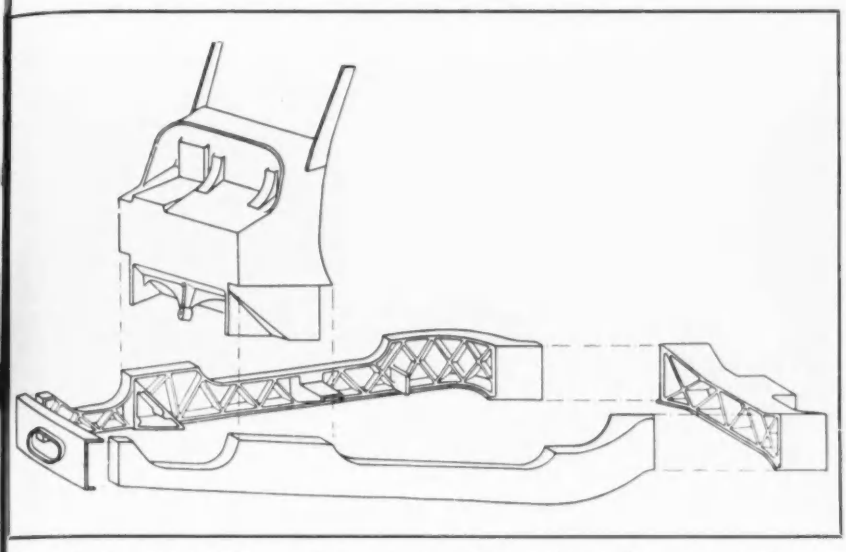

Fig. 3—Replacement of the complex steel sheet dashboard by a light alloy casting was suggested in this 1936 patent (Gregoire), which also included light alloy side beams.

PRODUCT ENGINEERING, Feb. 1947. A high strength light alloy casting, Fig. 1, carries the forward suspension and motorblock, spreading the stress over a large area of the panel.

The procedure of giving a rigid and sufficiently extended casting the job of spreading stresses over a large surface is important whenever the resistant structure consists of thin sheets. Whenever massive shapes are used the necessity for this spreading of effort is no longer felt.

One should recognize that this procedure of transposition has allowed interesting developments, which have given excellent results in practice. But the last examples cited show that the engineer logically ends by moving away from old solutions and that, by the force of things, he directs himself into new paths. Can one really imagine, on a steel body, having cast steel parts to spread stresses over a large surface of sheet?

SECOND SCHOOL: INNOVATION

This school makes a clean sweep of former solutions (it is difficult to arrive at this at the first attempt) and studies mechanical problems on the basis of the "mentality" of the new material.

One of the principal strong points of the light alloys, and especially of Alpax (Silumin), is their excellent castability. Now the key part of a passenger auto is beyond any doubt the dashboard assembly. In extreme simplification as in the Adler dashboard, Fig. 2, it is still composed of 13 parts Generally, the dashboard is made of 10 to 20 parts of stamped steel, welded together on mounting, straightened afterwards, the imperfections being corrected with much use of tin alloy. Everyone knows that French all-steel body builders still use impressive tonnages of tin, of which a good part goes to fill up the roughnesses of the dashboard.

Basic idea of the new technique was to replace this part, which is imprecise and costly in labor, by a cast part of high precision, thus suppressing a large part of the labor.

The development of this simplification theory found its first application in 1936 in the Adler car. To the dashboard, Fig. 3, constituting the key part, are bolted side beams tied in front and in the rear by cross beams. The side beams follow the exterior form of the body, in which they incorporate themselves. Cross section is in the form of a "U" of which the center is suitably curved. Inside the "U," reinforcement ribs confer great rigidity. The beams contain bosses and brackets for attaching the floor, forward and rear cross beams, and for passage of suspension organs.

Thus developed, the framework of the vehicle differs appreciably from the classical chassis. Mechanically, it fills the role of a chassis but it comes close to the "coque" in its incorporation into the body, of which it forms an integral part. It has seemed to us logical, for this reason, to designate this construction by the term "cast shell."

It is interesting to examine the evolution of the cast shell. One realizes then how difficult it is, when one abandons classical doctrines in order to create something incontestably new, to throw off a tradition in a single step. To convince oneself of this one need only compare, Fig. 4 a, b, c, the side beams of the 1936 Adler, the Amilcar Compound car built in 1938, and the Gregoire in its 1945 development.

In the Amilcar the side beams terminate at the mounting of the rear suspension organs, at the spot where rigidity is still indispensable to holding the road. The length of the foundry parts is thus appreciably reduced and their casting facilitated. The forward cross beam of cast light alloy, used in the Adler, remains the same. It is 4 mm thick when completely finished and supports the upper spring, the radiator, the steering, and the motor's rubber suspension pads. The tie is assured in the rear by a tubular beam of 1. 5 mm steel sheet on which are welded the two beams of the false chassis in the rear.

In the Adler the side beams still had a close relation to the traditional steel chassis beams. In the Amilcar they limit themselves to that part of

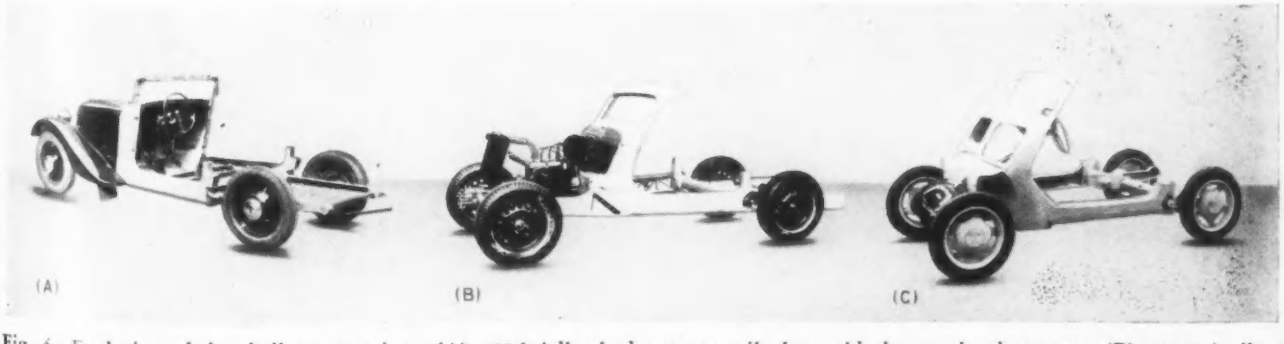

Fig. 4—Evolution of the shell construction. (A) 1936 Adler had unnecessarily long side beams, hard to cast. (B) 1938 Amilcar side beams extend only as far as rigidity is required. (C) 1945 Gregoire is built entirely around light alloy dashboard casting.

the structure which must remain indeformable. With the A. F.—Gregoire car the idea of an indeformable whole grouped around the key part, the dashboard, finds its full expression. In this car all revolves around the dashboard, which constitutes the center of the structure. For ease in casting, this dashboard has been divided into two parts, the lower dashboard, shown as the lead picture, which constitutes the real resistant element, and the upper dashboard which forms the frame for the windshield. The reader is referred to PRODUCT ENGINEERING, Dec. 1946, pp 88-92, for more pictures and details of this construction.

To this lower dashboard is fixed toward the front a part known as the forward support, on which are assembled the motor, steering gear and the suspension; and toward the rear, the side-beam panels. The latter are tied at the rear by a tubular steel cross beam and are prolonged by the small side beams, shown in Fig. 5, bolted to the tubular cross beam. These small side beams have bosses in which are lodged the articulation blocks for the rear suspension arms, shown in Fig. 6. These are also cast in light alloys.

ADVANTAGES OF CAST CONSTRUCTION

Such a whole no longer presents any analogy with classical construction in steel, compared to which it has numerous advantages:

1. Lightness. The shell of the A. F.—Gregoire weighs only 100 lb. This whole takes the place, mechanically, of the chassis, and replaces at the same time a part of the body; or in other words, 175 to 200 lb of stamped sheet in the most modern steel construction.

2. Rigidity. The following experiment was made on three cars: a normal car, all steel body bolted to tubular chassis; a specially rigid car, with body welded on a tubular chassis, or chassis-coque; and a cast-shell car.

One wheel was raised as high as possible, so that the car was on the point of tipping over; and the following facts were observed: on the first car, the doors could no longer be closed; on the second car, the doors could still be closed but there was visible, at opening and closing, a deformation of several millimeters in relation to the door frame; on the third car, with cast shell, the doors opened and closed just as if the car were on perfectly level ground.

3. Precision. The parts constituting the shell are straightened on templets after casting. They are drilled on a mounting. With the shell solution, the parallelism of the axles is assured in mass output to within several tenths of a millimeter, while with the classical technique, precision is on the order of several millimeters.

4. Solidity. With traditional construction it is difficult to spread over the thin steel sheet of the chassis or coque, the stresses transmitted by axles, springs, and shock absorbers. Despite reinforcements at the joints, which also involve an appreciable increase in dead weight, stresses remain locally elevated. All evidence indicates the shell does away with this inconvenience. Casting allows developing the parts to which the members are attached to the desired thickness. Moreover, a judicious tracing of ribs assures the spreading, over surfaces as wide as desired, of local stresses. The lightness of the shell, the possibility of varying the heights, the thicknesses and the ribbing, permits obtaining for parts of the shell (such as the side beam panels) moments of inertia from five to ten times higher than those of corresponding parts in steel. The work rate thus falls to 2-3 kg per sq mm, which, compared to the breaking point of treated Alpax of 24-28 kg per sq mm and to its limit of fatigue of 8-10 kg per sq mm, leaves enormous margin of security.

5. Ease of Repair. This question presents a considerable interest, too often underestimated.

After a collision the user must be able to repair his car quickly and cheaply. The car must also retain the same qualities as before the accident. Now repair of a classical chassis or a body-coque where the sheet is heated, hammered, pulled about, in a word "martyrised," can hardly claim to restore the same solidity and the same precision as before the accident.

On the other hand, in adopting for repair of shells the formal rule that all parts twisted or broken must be replaced, one is certain that the repaired car will benefit from the same mechanical qualities of precision and solidity as the new car.

The design of the shell should be such that the dismantling and reassembling of parts can be effected rapidly. A side-beam panel for example, if well designed, should be able to be changed in six man-hours. Changing or even straightening of a classical side beam, apart from the inconveniences noted above, is an infinitely longer operation and consequently more costly.

6. Noiselessness. Increasing the rigidness of cars without augmenting the weight has led, in the classical school, to adoption either of tubular side beams or of coque type bodies. All such progress made toward rigidity involves an increase in resonance of the frame on rough roads. With higher rigidity, the light alloy shell construction practically suppresses this noise. There are fewer joints, and therefore there is less possibility of noise.

7. Production Possibilities and Costs.

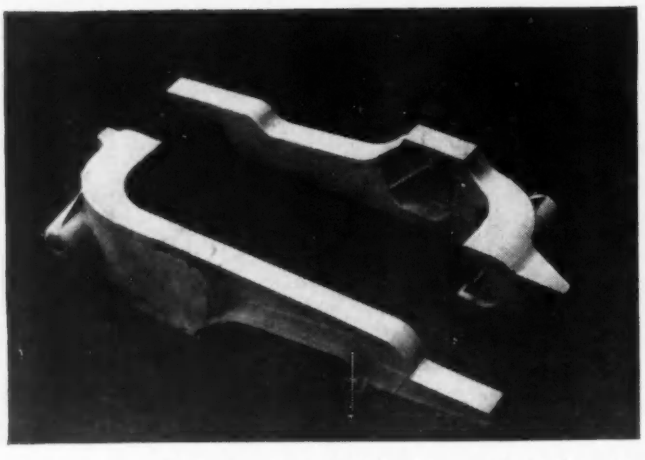

Fig. 5—Small side beams cast of light alloy are bolted to the tubular steel cross beam and prolong the main side beams.

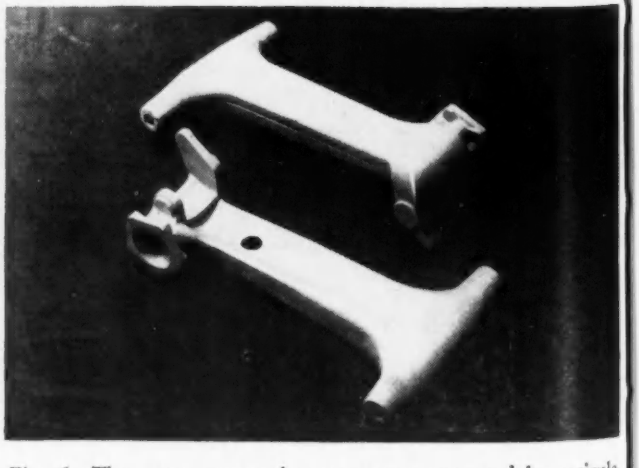

Fig. 6—These rear suspension arms are supported by articulation blocks lodged in the bosses of the small side beams.

Shell parts in Europe have been sand cast. This method, excellent for small or medium output, does not permit mass output as required in America. There is no reason why shell parts cannot be die cast. American machines are capable of pressure casting parts weighing up to 60 pounds. The weight of the cast dashboard of the largest passenger auto is no higher than 100 pounds. That is to say that already the largest dashboards can be die cast if divided into two parts. Specialists claim to be able now to cast parts of 100 lb under pressure.

As for the question of cost, indications can only be given for France for periods of stable prices as in 1939. At that time in France a pound of sand cast parts cost about 50 percent more than a pound of parts in stamped and assembled steel sheet, but the shell replaced twice its weight in steel parts.

A saving is thus involved in use of the shell. The difference becomes even sharper if one uses pressure casting. Then there is almost total suppression of labor; the parts come out rigorously precise, both in form and thickness, and require neither finishing nor retouching.

Improvement of Other Automotive Components

The use of light alloys has opened new horizons. The engineer has profited not only from the lightness and castability, but also from high heat conductivity, which allows rapid evacuation of the calories stored up by the drum during braking.

The first step in this technique has naturally been toward transposition. The classical brake drum, instead of being cast in steel, has been cast in light alloys, Fig. 7(*A*), around a hoop in special cast steel.

But despite undeniable progress brought by this method, the problem had not been reconsidered basically, with full disregard of the gradually perfected classical technique so solidly anchored in custom.

What reproaches could one make against this universally adopted technique?

First of all, the brake holder serves a similar purpose to the wheel holder. Secondly, the wheel holder prevents the flow of air from cooling the drum. Finally, the drum, despite its thickness, remains deformable.

Logic has thus led to the drum-wheel. The fixed wheel becomes the fixed rim, seen in Fig. 7(*B*), which facilitates changing. It also saves weight on the spare tire, being made either of cast light alloys or of steel sheet. The drum becomes the drum-wheel. It is composed of a hoop in special cast steel lodged in a cast light alloy part which serves as brake drum and wheel body.

When the brake is relatively small compared to the rim, a star perpendicular to the median plane of the hoop cylinder forms with the exterior of the wheel a caissoned and ribbed solid, light and highly rigid. The A. F.—Gregoire car drum-wheel is illustrated in Fig. 8. When the brake is relatively large compared to the rim, required by heavier cars, the drum takes the exterior shape of the wheel's body. This drum carries an important median rib, to which are attached the connecting pins of the fixed rim.

Advantages of Light Alloy Drum-Wheels

One obtains in this fashion a much more efficacious braking, with the same brake, because of the complete indeformability of the drums; a much more rapid evacuation of the brake heat, the drum-wheels acting as good radiators; and a notable lightening of the unsprung members, which help to improve the ride.

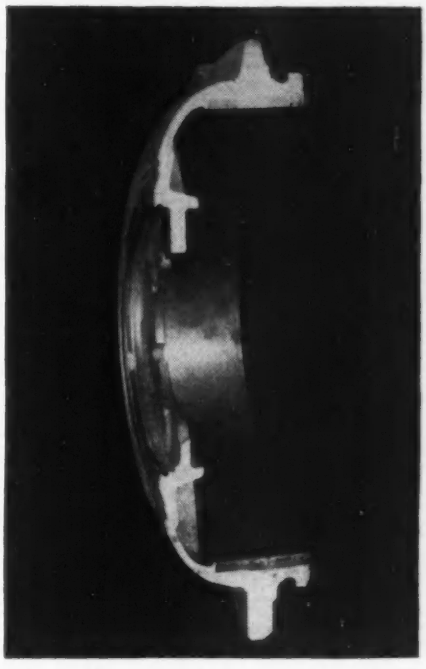

Fig. 8—Drum-wheel for a heavier (2,000 cc) car. Median rib adds strength and supports connecting pins for wheel rim. The drum is thus restrained from warping.

Conclusion

It follows from the several examples we have described that the only logical method of using new materials in mechanical construction is that of innovation.

This school is moreover productive of progress. It can lead to new solutions which are intrinsically superior to the classical solutions. That is why the research and use of new materials such as the light alloys and plastics should be encouraged in all types of industrial machinery parts.

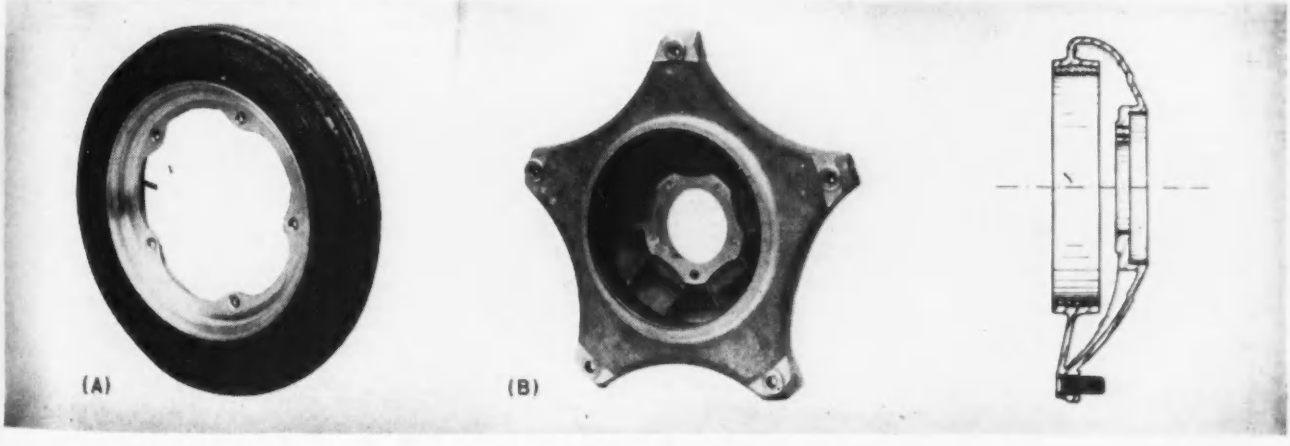

Fig. 7—Tires (A) are mounted on a small fixed rim in the light alloy drum-wheel construction. This design (Gregoire patent) is being used on the new French cars, the 4 hp Renault, Dyna-Panhard, DeRovin, Gregoire, and others. (B) Drum-wheel for a small car cast in light alloy. The interior is heavily ribbed for rigidity. Air has adequate access to the brake drum region.

Operating Characteristics of Industrial Solenoids-I

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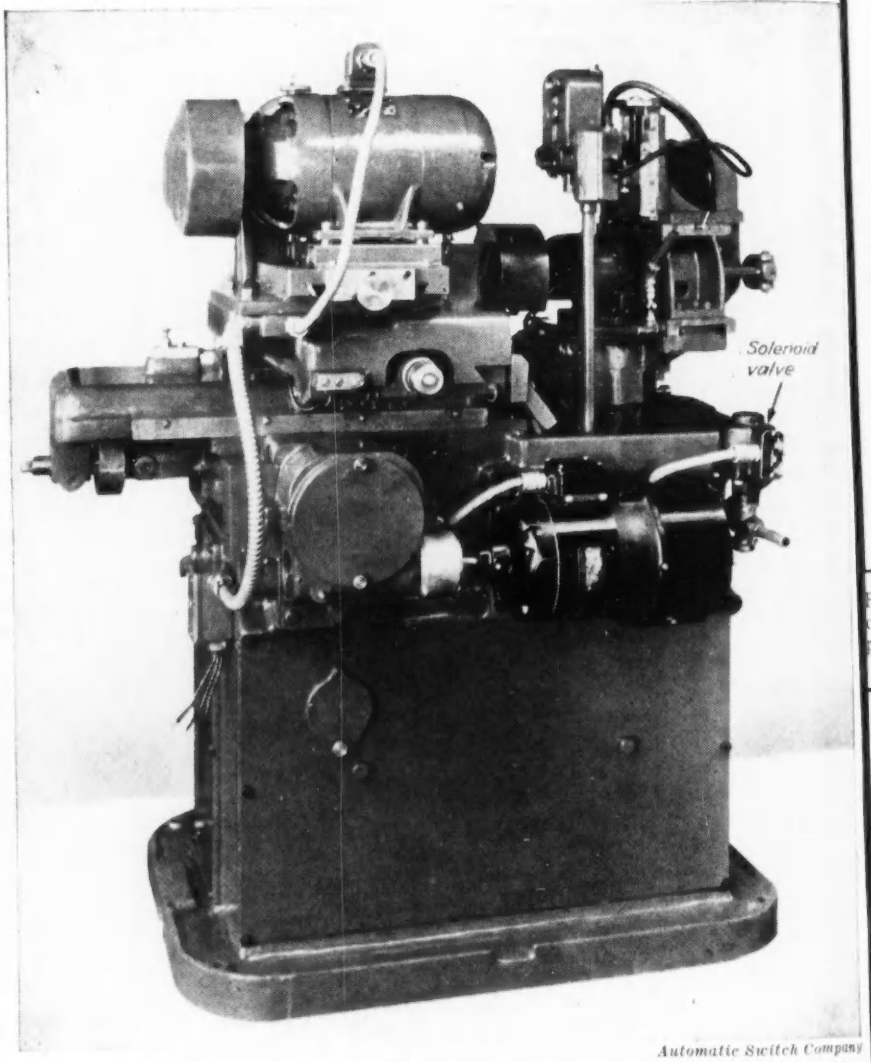
A SOLENOID is an electromagnetic coil whether or not an electric current is flowing in its turn or turns. Thus a short-circuited secondary coil or a metal tube carrying an induced current is a solenoid. When provided with a ferromagnetic core or plunger, the combination becomes a long-range electro-magnet or straight-line electric motor without pivots or bearings other than the guide for the plunger. Electrical energy in such a coil-and-plunger is converted into magnetic energy, useful work, and useless heat.

General Characteristics

A coil-and-plunger with a ferromagnetic frame or jacket is an iron or steel-clad solenoid and several forms are shown in Fig. 2. Such a solenoid with a ferromagnetic stop often is called a plunger electromagnet. These types are used extensively in both d-c and a-c circuits for operating magnetic switches in control and protective apparatus, and for actuating devices such as magnetic valves and magnetic brakes. Frames and plungers of d-c solenoids can be of solid iron or steel, but those of a-c solenoids are laminated.

Solenoids can be designed to (1) produce long or short strokes; (2) accelerate their loads quickly or slowly; (3) operate intermittently or continuously; and (4) remain in their closed positions briefly or for any length of time. Solenoids can deliver strong impacts or hammer blows that are useful in electric hammers; although usually sharp impacts are avoided in most industrial applications of solenoids. Solenoids either pull or push their loads, depending upon the end of the plunger to which the load is attached.

A solenoid does two kinds of work in moving its load: The so-called lifting work and the accelerating work. The efficiency of an a-c solenoid usually is about double that of a d-c solenoid. This is because during an active stroke of a d-c solenoid the magnetic energy not expended as useful work is stored in the system until the electric circuit is opened; then it is dissipated in the coil and switch contacts as heat.



Automatic Switch Company

Fig. 1—Solenoids are widely used for interlocking the operating sequence of machine elements, such as this electrically operated valve for controlling the flow of coolant. Solenoid valves are also used for the remote control of hydraulic devices

In a properly designed a-c solenoid, much of the magnetic energy stored during any quarter-cycle is returned to the electric circuit during the following quarter-cycle. One estimate of the overall efficiency of a short-stroke experimental a-c plunger electromagnet used in an electric hammer is about 89 percent. This consists of 52 percent for the lifting work and 37 percent for the accelerating work, as compared to a maximum of 46 percent efficiency for a d-c solenoid with 32 percent for the lifting work alone. But such high efficiencies seldom are realized.

The plunger of a long-range a-c solenoid is moved by a series of rapidly recurring pulls. Well designed a-c solenoids are inherently quick-acting because they must start their loads during one-quarter cycle. If an a-c solenoid cannot start its load during that time interval it cannot operate at all. Quick-acting d-c solenoids generally follow a-c design.

Differential Action. In analyzing the action of a solenoid it is helpful

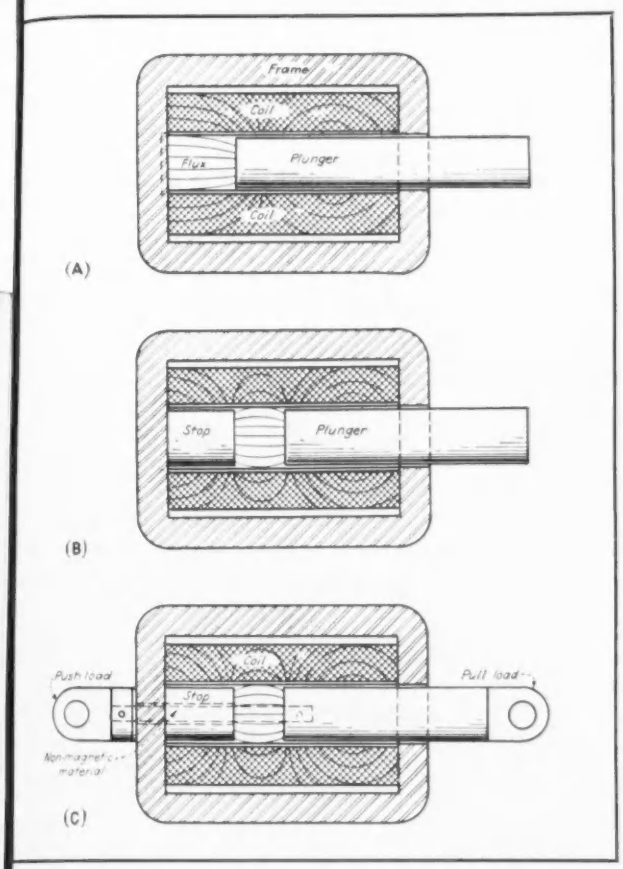


Fig. 2—Common types of d-c tractive solenoids. (A) Plain iron clad solenoid. (B) Plunger electromagnet with stop to increase pull. (C) Load can be pushed or pulled by solenoid.

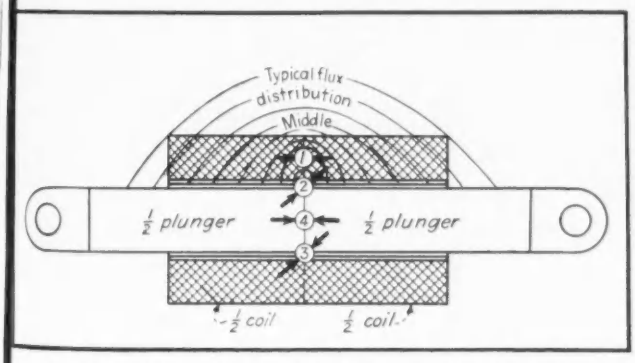


Fig. 3—Solenoid can be considered as two abutting coils and two abutting plungers. Final pull is sum of four separate pulls; pull No. 1 is least. No. 4 is strongest with short air gaps.

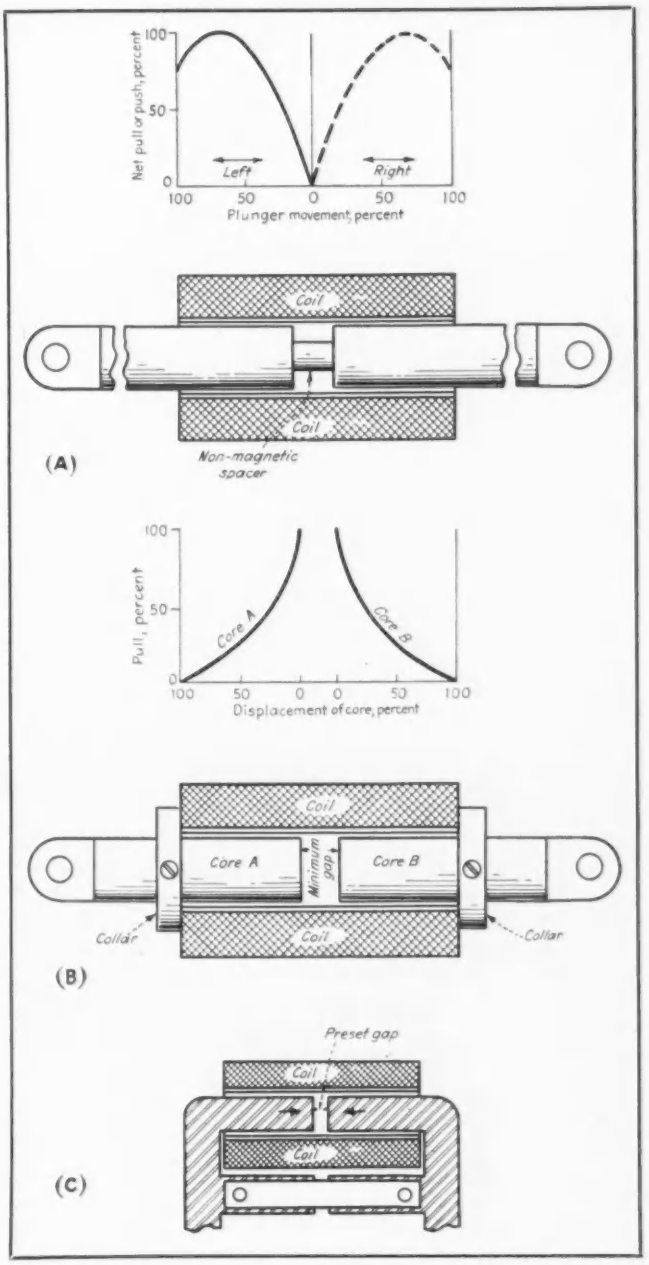


Fig. 4—Movement of characteristics of plunger. (A) With non-magnetic spacer between half-cores, net pull is difference between the opposed pulls. (B) Characteristic of preset gap between half-cores; pull of each half-core is measured separately with opposite section in place. (C) Brake solenoid uses pull between each half coil and opposite half-core plus air gap pull.

to think of the coil as consisting of two abutting half-coils and the plunger as comprising two abutting half-cores as shown in Fig. 3.

The coil-and-plunger operates on a differential principle. Two opposed mechanical forces simultaneously try to move the complete plunger in opposite directions; the difference between the two opposed pulls is the measured pull. For simplicity, in the following analysis coils are assumed to be stationary in horizontal positions and the plungers movable axially inside the coils with negligible friction. Thus the weights of the plungers do not have to be considered as they do when coils are placed vertically.

The plunger is magnetized by current flowing in the coil. The plunger is pulled within the core hole by predominating magnetic attraction until its middle coincides with that of the coil and the two opposed mechanical forces balance one another. This action occurs whether the plunger is longer, shorter, or of the same length as the coil.

The mechanical force developed by the current-carrying coil and its plunger is caused by magnetic leakage from the (1) entering end of the plunger, (2) through the coil wall and (3) back to the opposite end of the plunger within and outside of the coil, thus linking the current in the coil. The mechanical force is proportional to the rate of increase in the linkage of current and magnetic flux, as the plunger moves into the coil and increases the self-inductance. It is theoretically possible to use the principle of virtual displacement in estimating the mechanical forces of solenoids. But this is not always practicable. This is because of incomplete linkages of current and flux and changes in permeability that cause

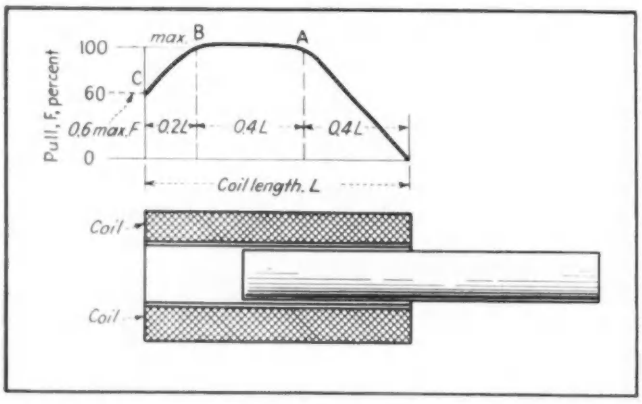


Fig. 5—Pull characteristic of constant current d-c solenoid with plunger longer than coil. Constant current a-c solenoid with laminated plunger gives similar characteristic.

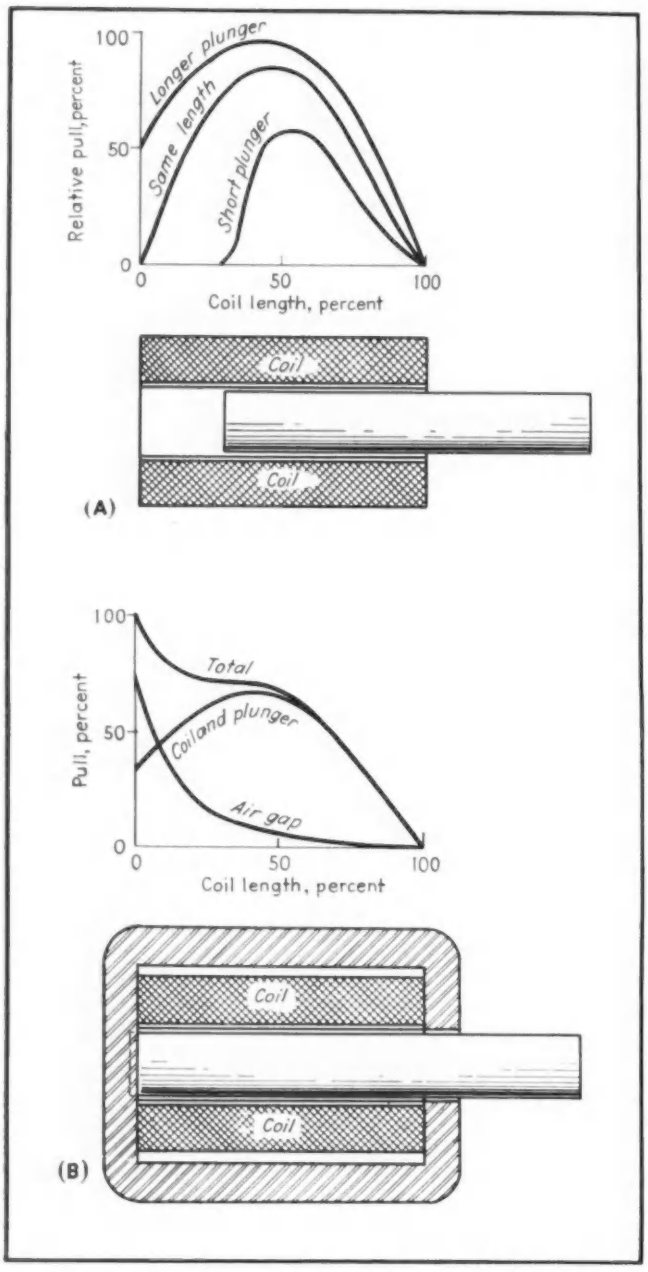


Fig. 6—With constant ampere turns for either d-c or a-c; (A) Effect of length of plunger with respect to length of coil in simple solenoid with no frame or stop; (B) iron clad solenoid with plunger longer than frame.

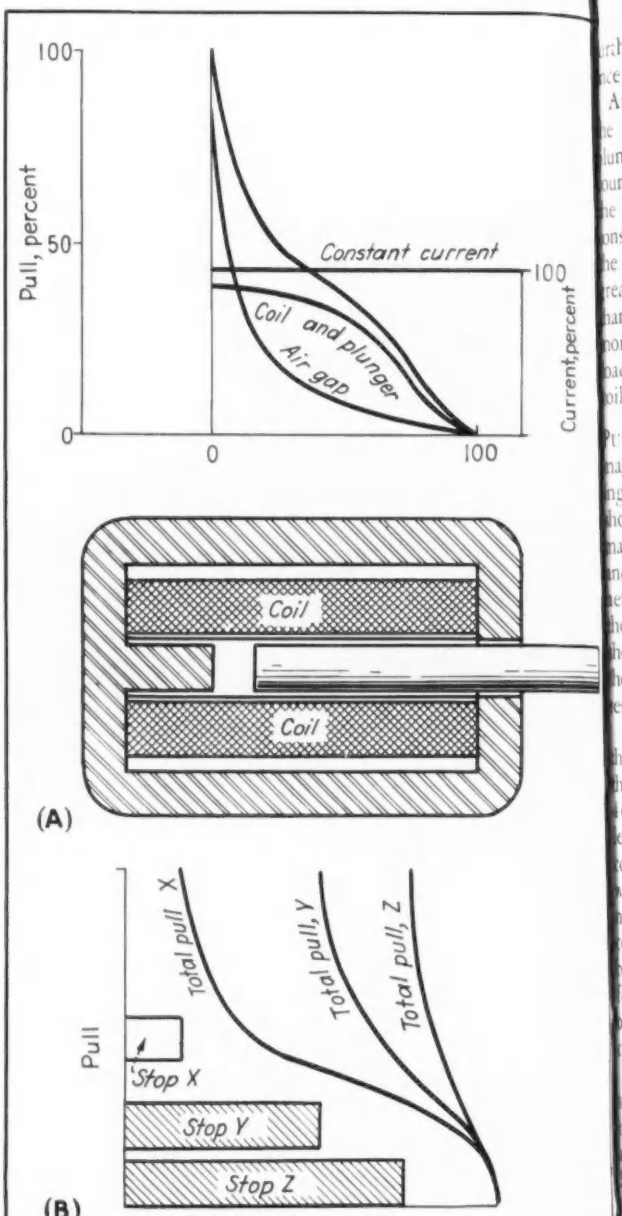


Fig. 7—Effect of length of stop on solenoid pull with constant current. (A) Total pull is sum of coil-and-plunger and air-gap pulls. (B) Total pull characteristics for three lengths of stop

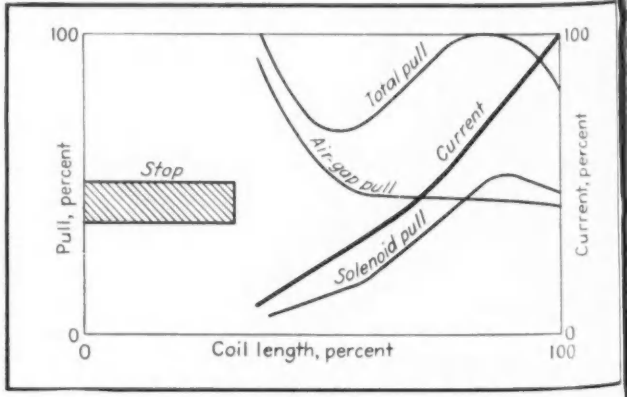


Fig. 8—In a constant voltage a-c solenoid the coil impedance increases as plunger enters coil. This decreases coil current and pull. Shape of pull curve can be altered by adjusting the position of the stop. Compare with Fig. 7 (A).

rther variation in the self-inductance.

Any relative linear motion between the current-carrying coil and the plunger of a d-c solenoid generates a counter-emf. This back emf reduces the effective current strength of the constant voltage d-c coils. Therefore the pull of d-c coil-and-plunger is greater with a slowly-moving plunger than with a fast-moving one. But the more slowly a d-c solenoid moves its load the greater is the heat loss in the coil per stroke.

PULL CHARACTERISTICS. When the magnetic middles of a current-carrying coil and its plunger coincide, as shown in Fig. 2, the magnitude of the magnetic flux, and linkage of current and flux are a maximum. Then the net mechanical force tending to move the plunger as a whole is zero. As shown by Fig. 3, an attempt to move the plunger in either direction will be resisted by a mechanical force.

Placing a non-magnetic spacer in the air gap between adjacent ends of the two half-cores, as shown in Fig. 4(A), produces unbalanced forces unless the middle of the plunger and coil coincide. The action is the same whether the solenoid has a frame or not. A slight displacement of the cores in either direction upsets the balance and one of the half-cores is forced out of the complete coil as the other half-core moves further into the coil.

This characteristic is used when slight displacements and small mechanical forces act to produce quick and powerful electromagnetic actions. Sometimes mechanical stops, such as collars on the two half-cores as shown in Fig. 4(B), are used to prevent such movement. Under this condition any withdrawal of the half-cores is resisted by a strong air-gap pull plus the solenoid pull, as in plunger electromagnets. This is true, with or without a frame. There are four separate mechanical forces acting to pull such a combination together as shown in Fig. 3: (1) Pull between the two half-coils; (2) and (3) the pull between each half-coil and each opposite half-core, and (4) the air-gap pull between the two half-cores.

Pull (1) is relatively insignificant and is not used in solenoids; only one of the pulls (2) or (3) is available in a coil-and-plunger; and pull (4) is the principle one in plunger electromagnets with short air gaps. The coil-and-plunger pull often is negligible in designs with short air gaps because the air-gap pull (which is limited by the magnetic saturation of the plunger and the stop) is so much stronger. But with relatively long air gaps the sum of the coil-and-plunger and air-gap pulls should be considered. The brake solenoid shown in Fig 4(C), uses the (2), (3) and (4) pulls.

The pull of a d-c coil-and-plunger is limited only by the strength of the current that the coil can withstand. After the plunger is saturated the pull increases directly with the number of ampere turns in the coil.

The approximate pull characteristic of a typical d-c or a-c coil-and-plunger with the plunger longer than the coil, operating on constant current is shown in Fig. 5. About the same curve for the coil-and-plunger only is obtained for an iron-clad solenoid or plunger electromagnet. By utilizing only the pull from O to A; A to B, or B to C; accelerating, nearly uniform, or decelerating pulls can be obtained respectively. Within limits, the longer the plunger relative to the coil the (1) stronger is the coil-and-plunger pull as the entering end of the plunger reaches the opposite end of the coil and (2) the longer is the useful range or stroke. Some of these pull relations for different lengths of plungers are shown in Fig. 6, including the effect of adding a frame and stop.

Unless data from past experience are available, the preliminary design of a coil-and-plunger usually is based upon test data obtained with solenoids having stationary plungers. Here the only energy loss is caused by the resistance of the coil. Tests of symmetrically wound d-c solenoids with flat-end round unannealed cold rolled steel plungers of various lengths and uniform cross sections showed that in all tests a maximum pull (or push) of about 9 or 10 psi of plunger cross section is obtained for each 1,000 amp turns per in. of coil length when the plunger had entered about two-thirds of the length of the coil, as shown in Fig. 5. Use of the best grades of annealed steels increase the pull about 20 percent.

For symmetrical solenoids with flat-faced unannealed cold rolled steel plungers, as well as for the more common steels and wrought iron, the approximate maximum coil-and-plunger pull can be calculated simply. Where NI is the number of ampere turns, L is the length of the coil and L_g is that of the air gap, both in inches, pull in psi is

$$\frac{F}{S} = 0.009\,\frac{NI}{L} \qquad (1)$$

and that for the air-gap between a flat-faced unsaturated plunger and a flat-faced stop, is approximately

$$\frac{F}{S} = 1.4 \times 10^{-7}\left(\frac{NI}{L_g}\right)^2 \qquad (2)$$

Equation (1) holds when: (1) The length of the coil is at least twice its diameter; (2) coil diameter is not greater than three times that of the plunger; and (3) the stop projects into the core hole about one-third the length of the coil. As shown in Fig. 7, the length of the stop affects the pull characteristic of a d-c solenoid.

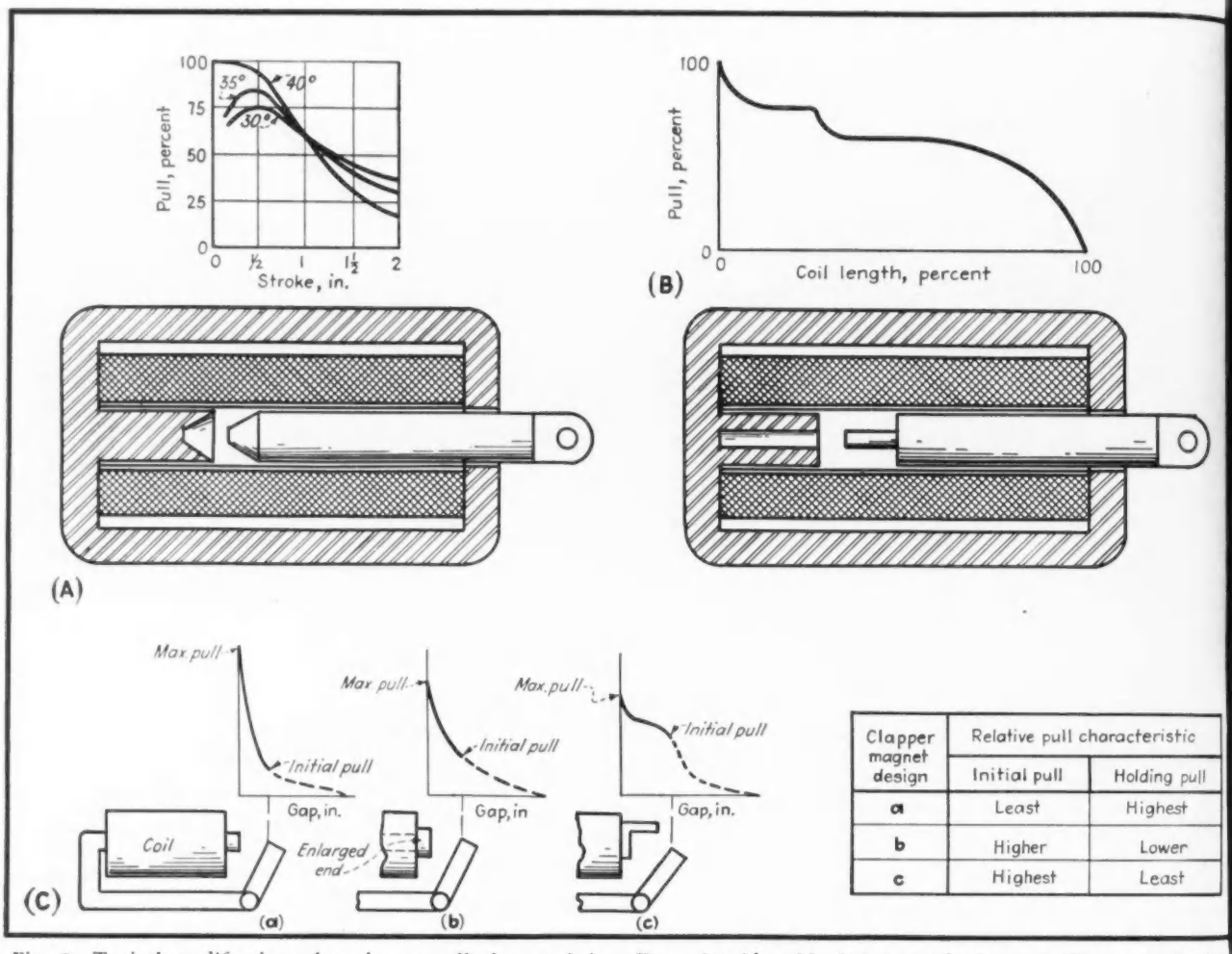
The total pull of an iron-clad solenoid or a plunger electromagnet is the sum of the coil-and-plunger and air-gap pulls. Thick frames for solenoids are necessary only for mechanical strength requirements; such as in heavy duty solenoids that act with great force through a short air gap. In such solenoids it is well to allow an extra assumed air gap of $\frac{1}{4}$ in. because of plunger reluctance and leakage.

The static pull characteristics of constant-current a-c solenoids are similar to those for constant-current d-c solenoids except that from 10 to 20 percent more ampere turns may be required if a shading ring is not used. This is caused by secondary-current and hysteresis losses in the plunger, stop, frame and other parts. In the closed position, the shading ring of a plunger electro-magnet naturally causes an increase in the main coil current for that position.

Constant-voltage d-c solenoids have static-pull characteristics similar to those of constant-current d-c solenoids except that heating increases the coil resistance, thus reducing the number of ampere turns and the resulting pull. To assure adequate pull after coils are hot, it is well to design the solenoid for 25 percent more ampere turns and pull than that calculated on the basis of room ambient.

Constant-voltage a-c solenoids have entirely different pull characteristics. As the plunger moves into the coil the impedance increases, thus reducing the current strength and the pull. The effect is shown in Fig. 8 which can be compared with Fig. 7(A). The pull curve can be altered by changing the position of the air gap. If the current in an a-c plunger electromagnet decreased directly with the forward movement of the plunger and the total reluctance was in the air gap, the air-gap pull would be constant. But as shown in Fig. 8, this is not true.

Solenoids are preferably mounted in a vertical position. This minimizes friction and wear, avoids use of retractile springs, and lets dirt fall out of the core hole. Effective tractive effort for a vertically mounted solenoid equals the difference between the electro-tractive pull produced and the weight of the plunger. Since both the



Clapper magnet design	Relative pull characteristic	
	Initial pull	Holding pull
a	Least	Highest
b	Higher	Lower
c	Highest	Least

Fig. 9—Typical modifications that change pull characteristics. D-c solenoids with (A) tapered plunger; (B) magnetic shunt. Clapper-type electromagnets (C) showing modifications to vary ratio of initial pull to holding pull.

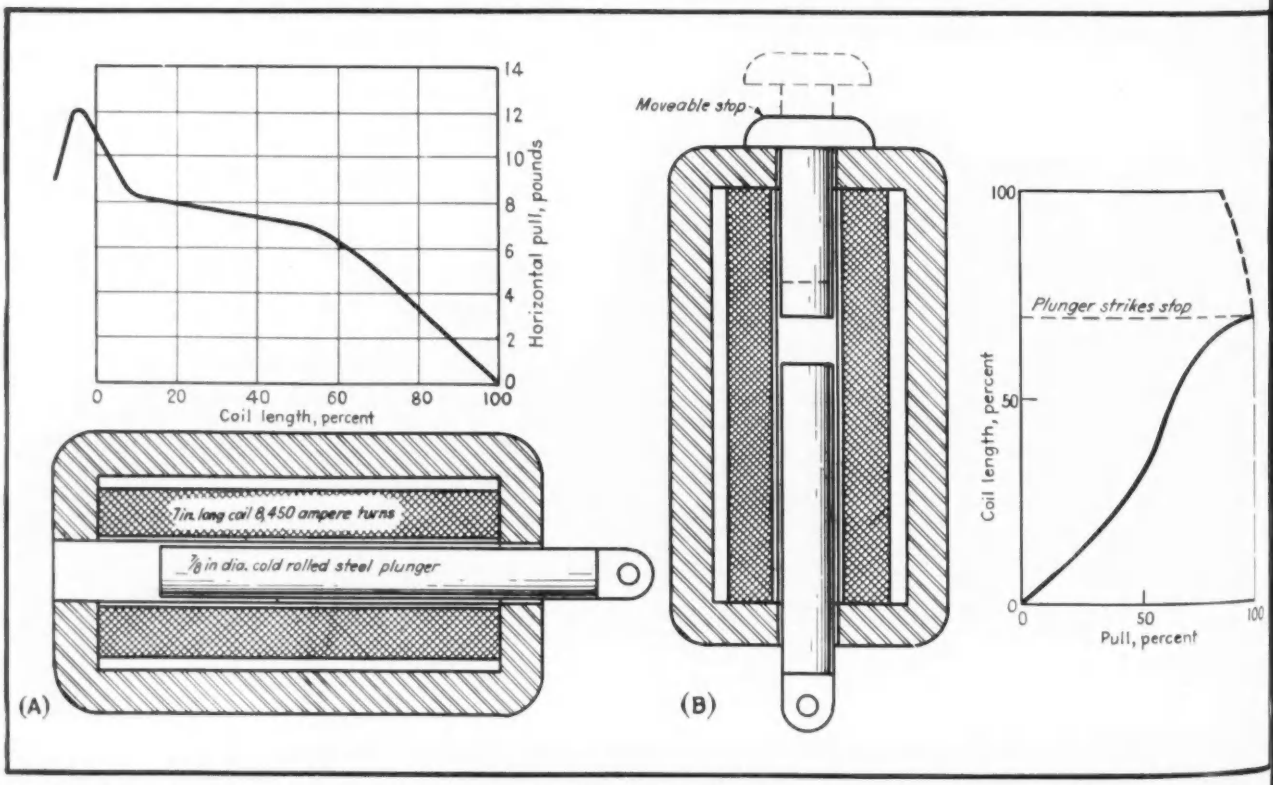
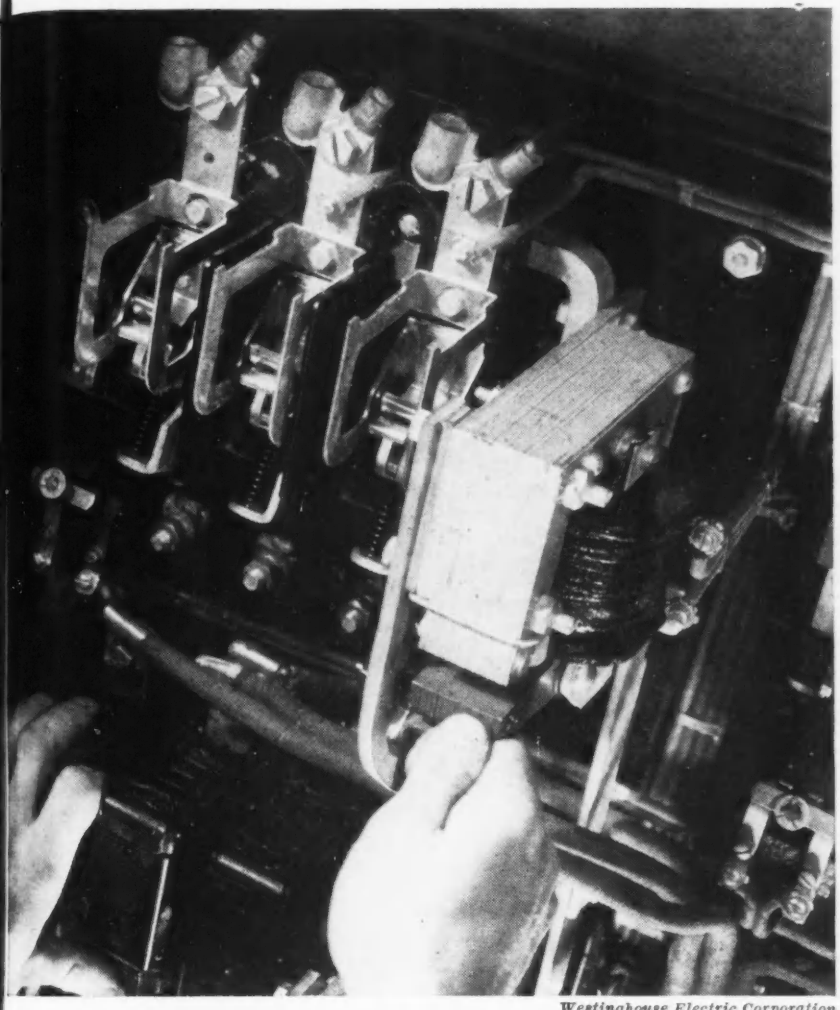


Fig. 10—Combating effect of hammer blow in d-c solenoids. (A) Hole through frame gives magnetic cushion, as shown by test data. (B) Floating stop moves when struck by core to reduce "mushrooming" effect of impact.



Westinghouse Electric Corporation

Fig. 11—Typical magnetically operated a-c contactor. Core material is laminated to reduce losses that would result from the alternating flux in a solid core.

tractive pull and weight of the plunger vary directly with the cross section, nothing is gained in effective vertical pull by increasing the cross section of the plunger.

Modifying Pull Characteristics

The pull characteristics of a d-c coil-and-plunger may be changed by unevenly distributed ampere turns along an assymetric coil, or by varying the cross section along the plunger, or both. Thus the initial and final pulls can be increased to obtain a more uniform distribution of pull, especially for intermittent service or for certain electrical instruments where the current is relatively weak.

Tapering the entering end of a plunger longer than the coil in an unframed solenoid increases the useful d-c range; but this decreases the maximum pull and changes the position of maximum pull with respect to the middle of the coil. Different pull characteristics in both d-c and a-c plunger electromagnets can be obtained by changing the length of the stop.

Different pull characteristics can be obtained with differential solenoids. For example, two spaced coils can be used with a single connecting plunger or with a single differentially-wound coil acting on a single plunger. Often toggles and other linkages provide useful modified pull characteristics in d-c solenoids; but they are rarely used in a-c solenoids because of noise.

The initial pull and the length of stroke can be increased in d-c plunger electromagnets in several ways as shown in Fig. 9. Coning the plunger and its co-acting stop as shown in Fig. 9(A) increases the effective area of the air gap and reduces its reluctance for a given length of gap. For example, one design uses a vertical plunger electromagnet 6 in. high and $6\frac{1}{2}$ in. diameter with a male coned stop 5.31 in. high, 3.44 in. diameter at its base, and with its apex projecting to the top of the frame. With its co-acting female coned plunger and 15,500 ampere turns in its coil, a pull of 200 lb was obtained at the beginning of a 1 in. stroke and 135 lb at the beginning of a 2 in. stroke. The direct pull across such air gaps is at an angle with the axis of the gap and only the resultant pull is effective. Coned plungers and stops are seldom used in a-c plunger electromagnets.

The magnetic shunt principle is applied to d-c plunger electromagnets such as shown in Fig. 9(B). The initial pull is increased by an auxiliary plunger moving into an enlarged hole in the stop. In such shunt arrangements the maximum pull is correspondingly less.

The hammer blow in a solenoid is caused by the highly accelerated plunger striking the co-acting stop. After long periods, hammer blows harden and distort the ends of soft steel plungers and stops. In d-c solenoids, co-acting surfaces can be suitably hardened. In a-c solenoids, sometimes welding hard nonmagnetic material on the co-acting ends of both the plungers and the stops prevents mushrooming.

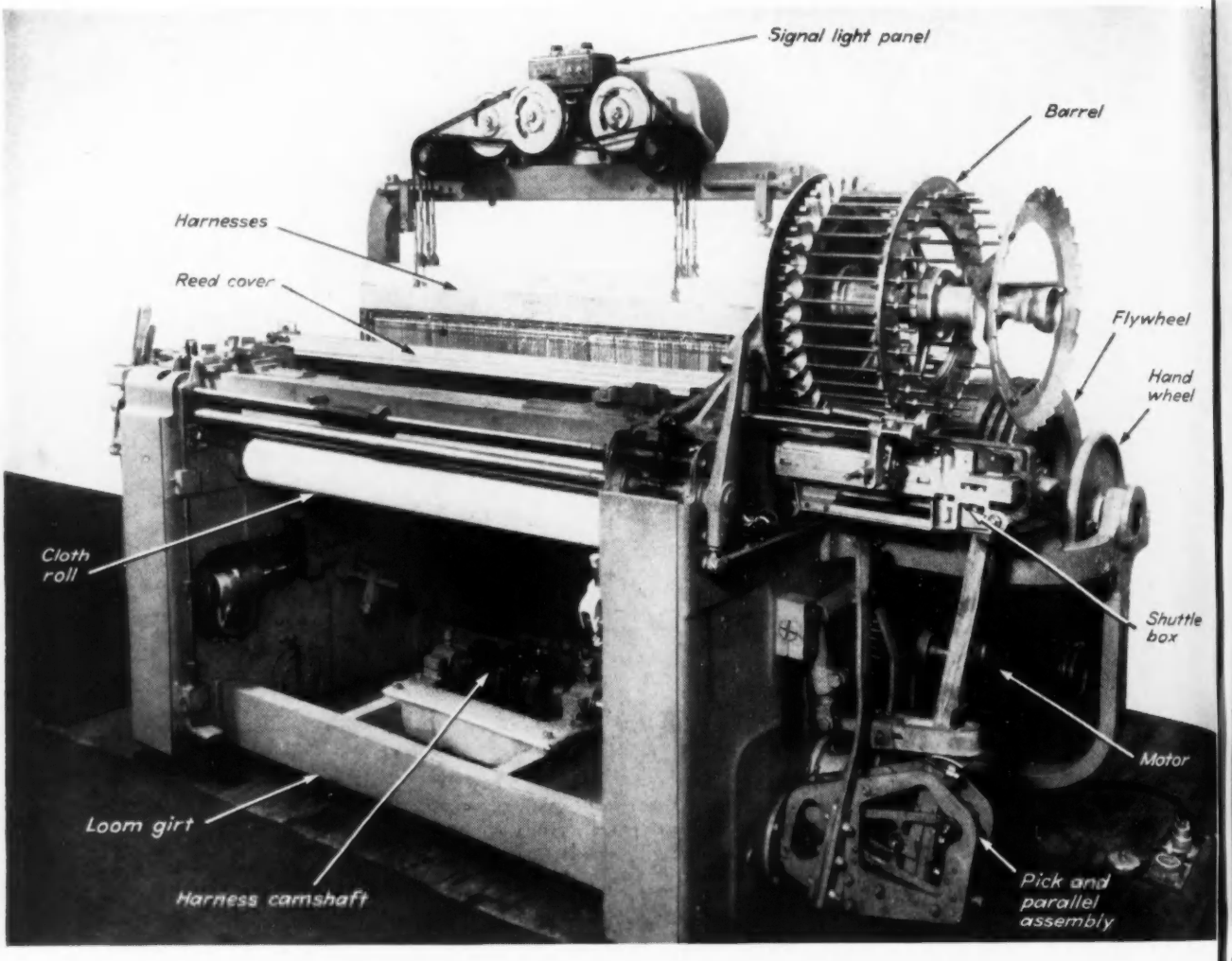
A hammer blow is avoided in the magnetic cushion type of solenoid that has a hole through the frame where the stop ordinarily is located, as shown in Fig. 10(A). But this solenoid has weak holding properties since the pull does not increase rapidly near the end of the stroke.

The hammer blow is reduced in the plunger electromagnet with the floating stop shown in Fig. 10(B), since at the end of the stroke the stop momentarily moves upward with the plunger.

Inherently a-c solenoids are noisy. Although shading rings insure quiet operation of single or polyphase solenoids up to certain limits of pull, they usually are noisy with increased load, wear, or the presence of dirt. Elevator brake solenoids in hospitals, hotels and apartments are immersed in oil to deaden the noise. Flat springs are sometimes placed between coils and their supports to lessen vibration imparted to the coils.

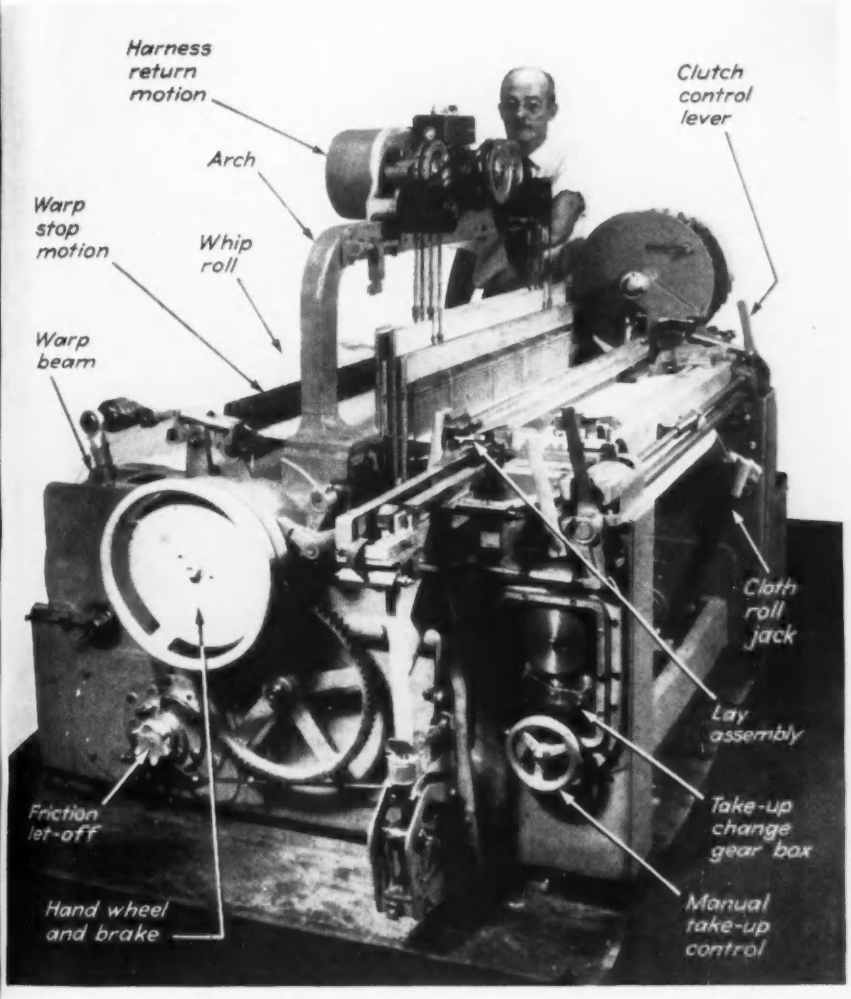
* * * *

First used in 1877, ball bearings came into general use with the advent of the modern bicycle. A high stage of development was brought about by the bearing industry as the automobile evolved from a curiosity to a practical means of transportation. Their marked superiority over plain bearings in these instances soon caused them to be used in all types of light machinery. However, ball bearings have not replaced journals.



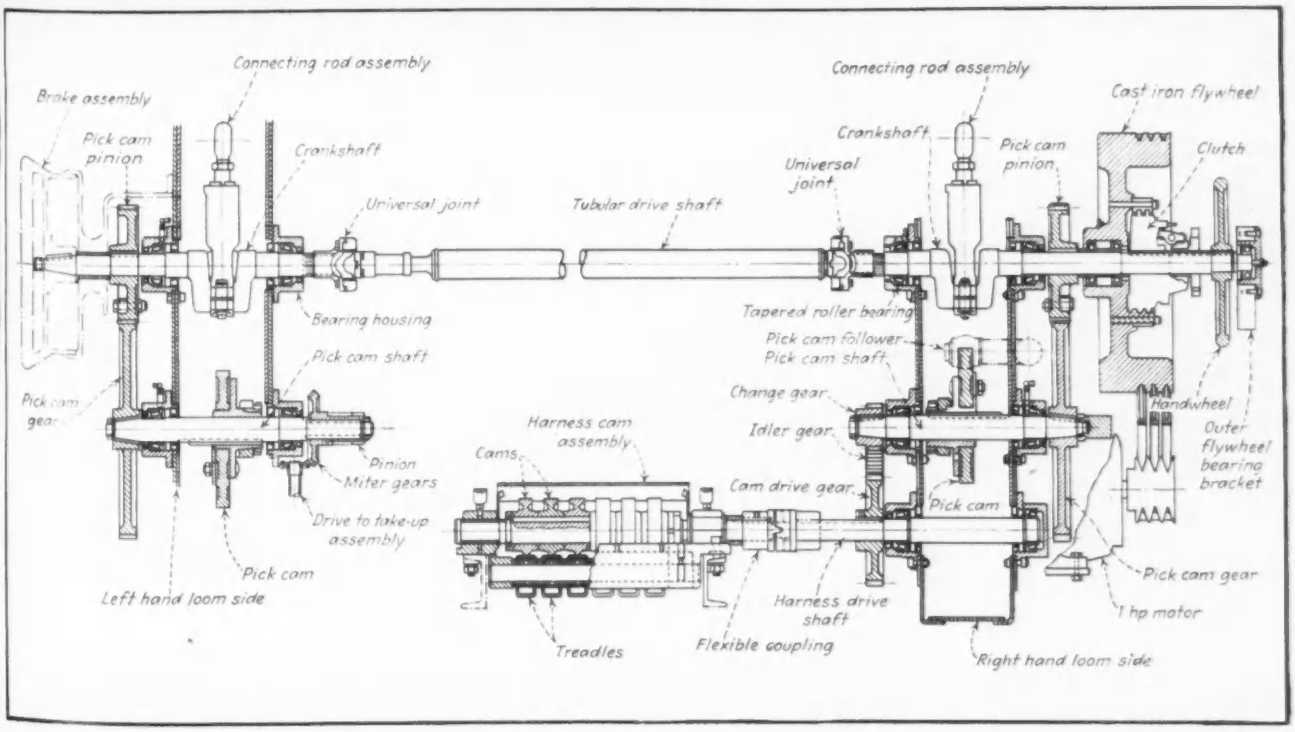
High Speed Cam Operated Loom

Having all the basic motions of a conventional loom, the Kellogg Model 100 loom is designed for high speed operation. Down time for repair operations has been reduced by designing all components as sub-assembled units. These units can be quickly removed and replaced with correctly calibrated units when breakdowns occur. High speed operation of 225 picks per min has been accomplished by specifying lightweight metals for many of the reciprocating parts. Added design features that have permitted high operating speeds are the use of cut steel gears and tapered roller bearings. Loom sides are weldments consisting of formed steel plates welded together. This box type construction avoids cantilevered supports for any of the power shafting or drive components. Misalignment problems that can result from this type of construction are avoided by using universal joints to transfer power from one loom side to the other. The arch on this loom is made of square steel seamless tubing welded to cast steel flanges. A similar type of design is used in the construction of the supports for the outer flywheel bearing. The loom sides are held in position by channeled frame members that are bolted and welded in place. Power is supplied by a 1 hp 850 rpm motor through a V-belt drive to the flywheel. Speed changes are made by changing pulleys on the motor shaft. The let-off motion for the warp beam is an adjustable clutch that consists of steel and bronze plates running in oil. Lubrication for the tapered roller bearings is provided by individual grease fittings. An internal friction shoe automotive type brake is provided to stop the loom motions instantaneously. This loom will weave either cotton or rayon material without making major changeover adjustments. Weight of the 40 in. loom less warp, is 3,100 lb. It is built in sizes from 40 in. to 60 in. width, by the M. W. Kellogg Co., Loom Division, Jersey City, N. J.

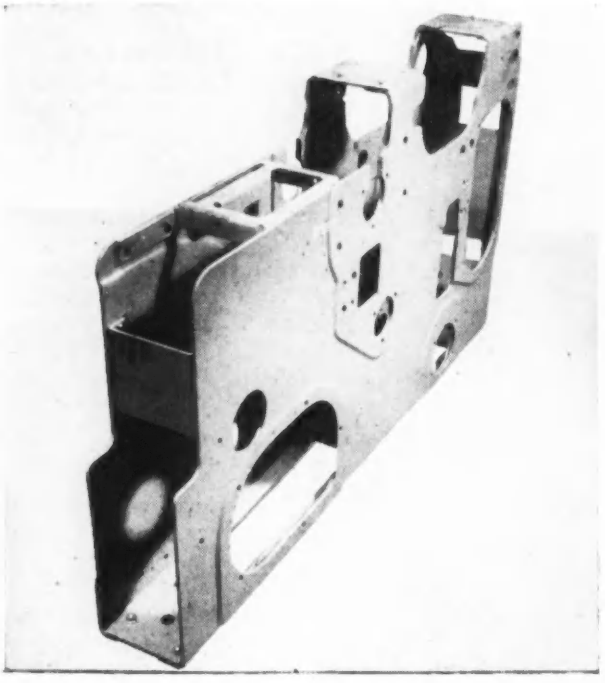


LEFT SIDE VIEW shows one of the hickory picker sticks that projects the shuttle that carries the bobbin, and accelerates it across the lay beam where it is struck by the other picker stick. The picker stick has a synthetic rubber and fabric receiver for the shuttle. The stick is provided with a cammed parallel motion that causes the end striking the shuttle to travel in a straight line.

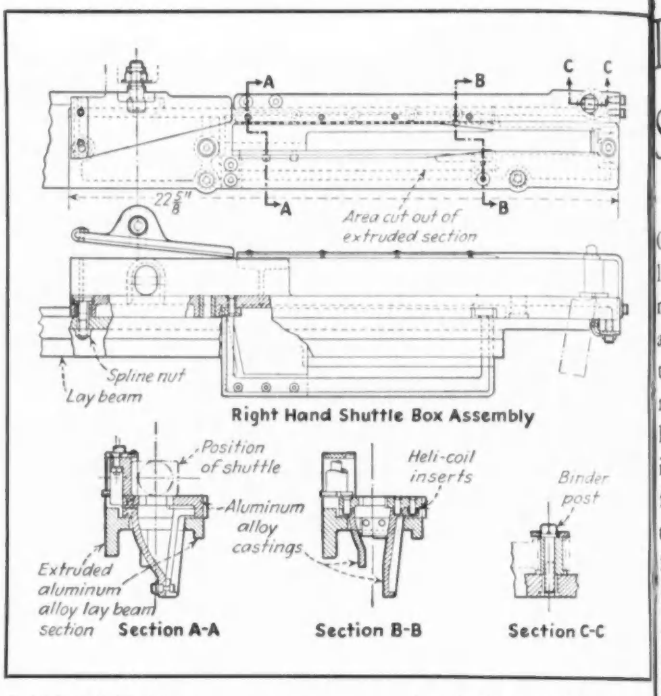
POWER DRIVE schematic shows the split crankshaft construction that is provided for the reciprocating lay motion. Universal joints mounted on involute splines on the end of each crankshaft are connected by a welded steel tubular shaft. Harness camshaft is mounted in the base of the loom. It is also provided with a flexible coupling to the harness timing gear shaft. The camshaft is made up of individual induction hardened cams whose surfaces are generated in relation to a key slot in the hub. Idler gear in the harness timing gear set can be swung out of mesh to adjust the lay and harness motion relation. To simplify maintenance, all tapered roller bearings supporting the separate shafts are identical.



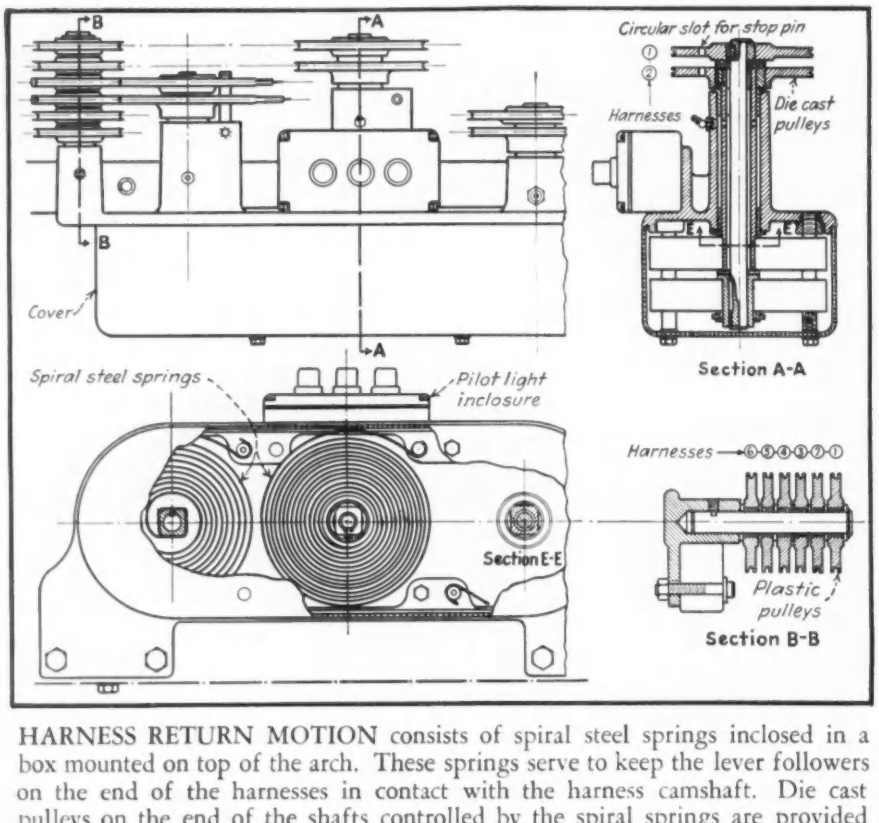
High Speed Loom (continued)



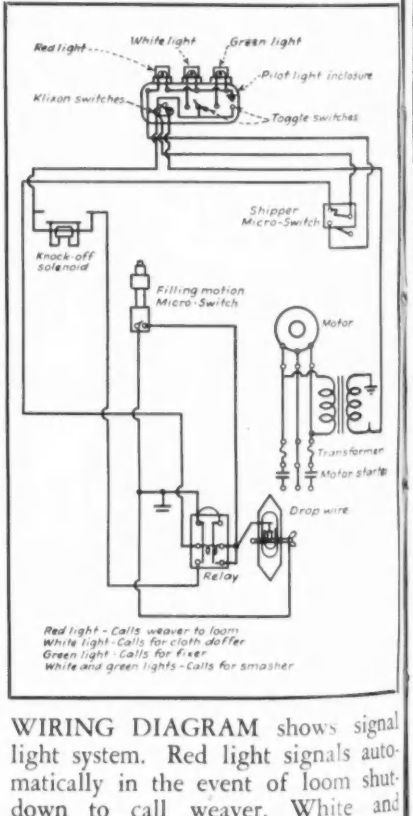
LOOM SIDES are $\frac{1}{4}$ in. SAE 1020 hot rolled steel. Sections are embossed, formed and pierced. Reinforcing strips are spotwelded in the embossed areas. The entire assembly is then spotwelded together. No holes are tapped in the loom sides. Holes are drilled in the sides to receive tapped spline nuts.



LAY MOTION components are made of lightweight materials to reduce the inertia effects of its reciprocating motion. The 8 ft long lay beam is an aluminum alloy extrusion. Shuttle boxes mounted on each end of the lay beam are made up of aluminum alloy castings bolted together. Slots for picker sticks are machined in the extruded sections.



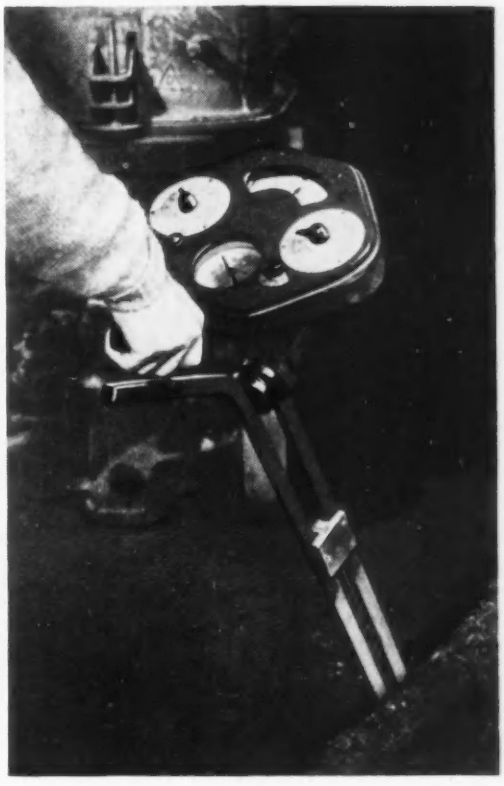
HARNESS RETURN MOTION consists of spiral steel springs inclosed in a box mounted on top of the arch. These springs serve to keep the lever followers on the end of the harnesses in contact with the harness camshaft. Die cast pulleys on the end of the shafts controlled by the spiral springs are provided with three holes for locating the end of the cables. Overtravel of the pulley is prevented by stop pins that extend through slots cast in the pulleys.

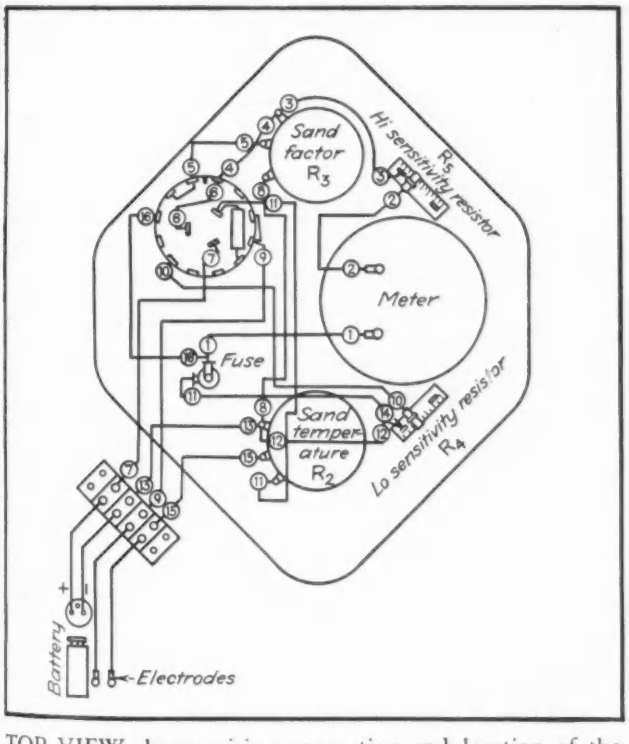


WIRING DIAGRAM shows signal light system. Red light signals automatically in the event of loom shutdown to call weaver. White and green lights controlled by weaver call for cloth remover or repairmen.

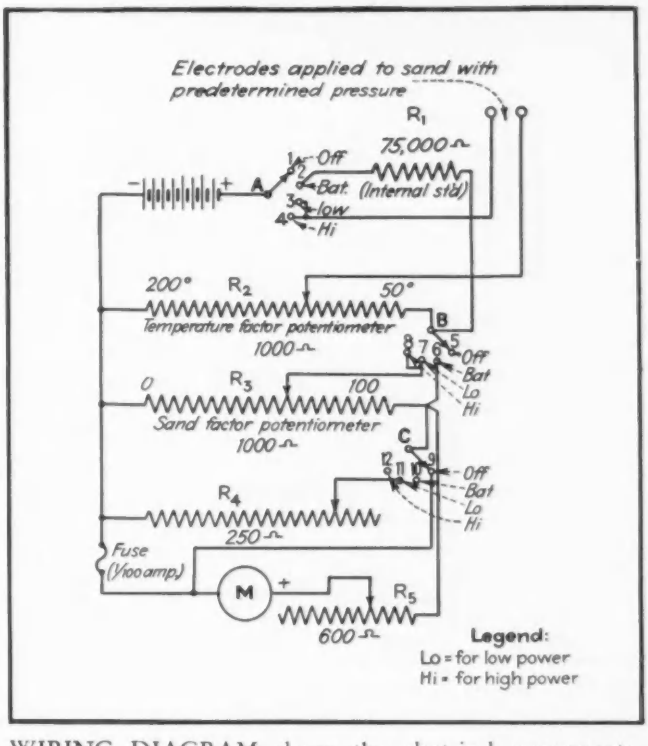
Instrument Gives Sand Moisture Content

Operating on the principle that electrical conductivity of a particular sand sample under certain regulated conditions depends upon its moisture content, the No. 285 Moistmeter has both corrosion resistant materials and shock resistant instrument mountings. To operate the instrument, it is inserted into a pile of sand, one of the handles is released and the moisture content read directly on a dial. Moistmeter has a light alloy housing for the metering devices. Housing is inclosed with a rubber bumper ring. Two stainless steel arms in the form of a pair of tongs are attached to the housing. On the end of the spring loaded fulcrum arm is mounted a curved sampling plate. Sand trapped within this plate is compressed to a predetermined hardness when the tongs are released. Provision is made for temperature compensation. The unit weighs 10 lb, has an overall length of 35¼ in. and has a maximum sampling depth of 25 in. It is manufactured by the Harry W. Dietert Co., Detroit, Mich.

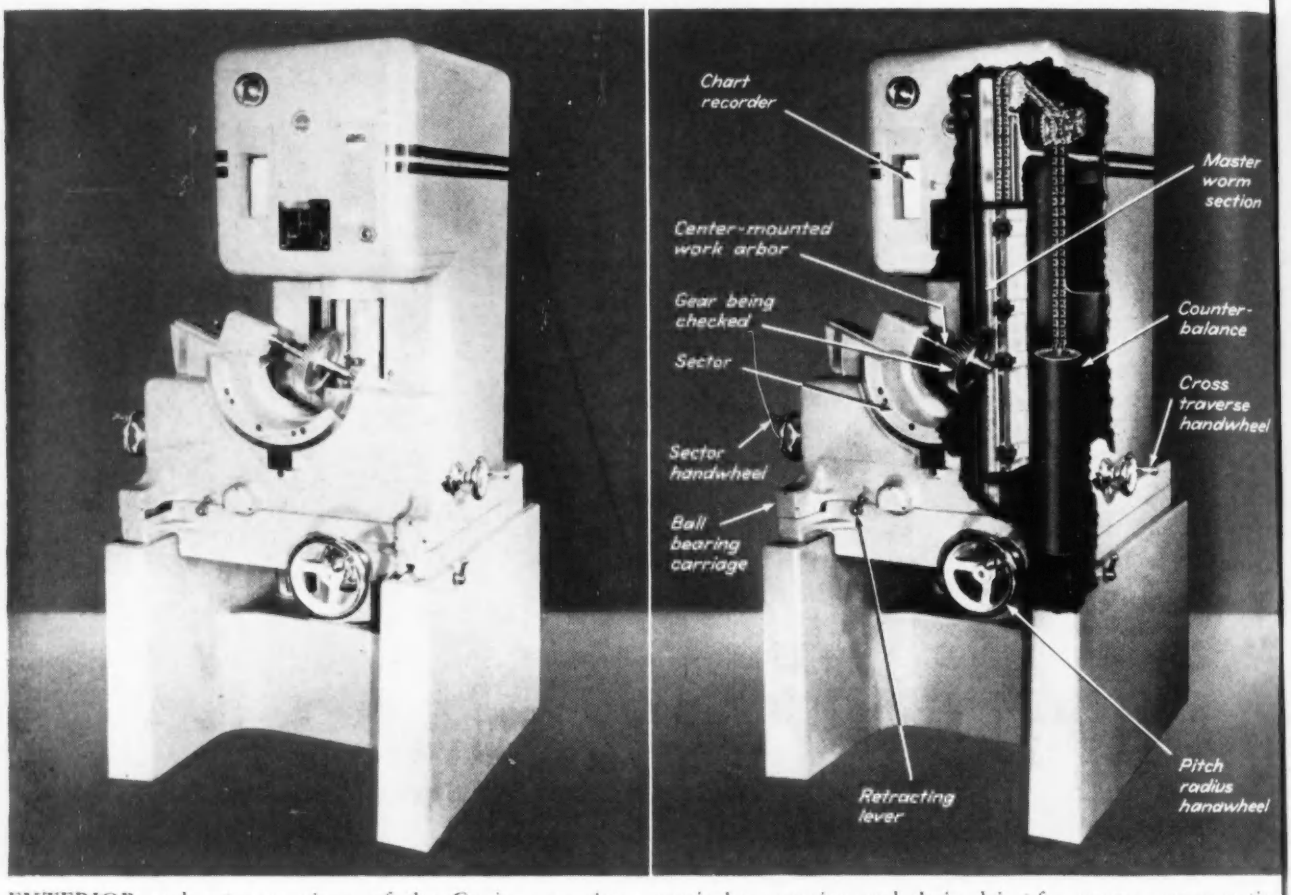




TOP VIEW shows wiring connection and location of the rubber mounted instruments. The Moistmeter is calibrated by adjusting the sand factor dial. The sand factor number is determined from analytical moisture determinations of a sealed sample. For example, a sample has been tested and found to contain 5 percent moisture. The Moistmeter is inserted into the sample and the sand factor dial adjusted until the meter reads "5 percent". Sand temperature dial is set to agree with the dial thermometer, the stem of which is mounted in the stationary arm.



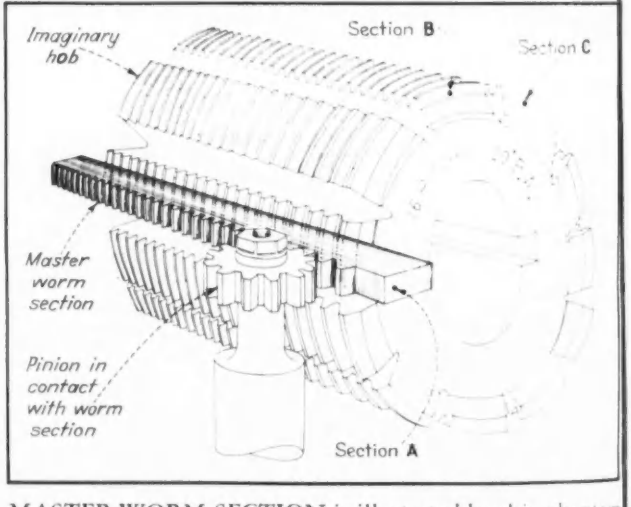
WIRING DIAGRAM shows the electrical components. Two electrodes are mounted in the tip of the stationary arm. The electrodes and their housing form a concentric circle with the curved sampling plate. Power is supplied by a 22½ v battery. The battery is discarded when it fails to give a 10 percent moisture reading. A battery checking switch position is provided. No tools are required to remove the battery, which is taken out of the instrument by raising a leaf spring. Readings can be taken at the rate of 10 per min.



EXTERIOR and cutaway views of the Conju-gage show vertical suspension and chain drive for master worm section

Worm Sectioned Gaging Element

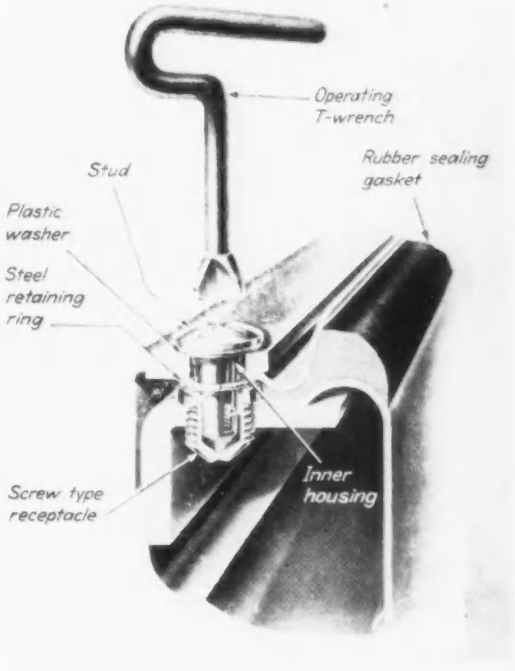
Designed to chart composite errors in both spur and helical gears, the Kodak Model 8-U Conjugage uses a gaging element that is ground as a section of a single thread worm. Two adjustments are provided: One for helix angle setting, and one for pitch radius. Helix angle is adjusted by revolving a sector through a worm drive operated by a handwheel. Another handwheel is provided to adjust the pitch radius, which is zeroed by bringing a master arbor in contact with a datum pad on the end of the worm. In operation, a gear is placed between centers and meshed with the worm section. A cycle switch is tripped and a synchronous motor drives the worm section along a Vee-way, imparting rotary motion to the gear. Gear errors are indicated by center distance variations. These variations are transmitted to a differential transformer in which a center coil moves between two fixed cores with opposing fields. The output of the moving coil is amplified and recorded on a moving chart, visible through a glass panel. The Conju-gage is built by Eastman Kodak Company, Rochester, N. Y.



MASTER WORM SECTION is illustrated by this phantom drawing. The master section "A" differs from Imaginary forming hob sections "B" and "C" since no cutting clearances are provided. Since teeth on the master are sections of an involute helicoid, crown and taper can be checked by traversing the gear across the worm. Recording mechanism can be adjusted for 100, 200, 400 and 800 to 1 magnification. Maximum capacity of the conju-gage is $8\frac{1}{4}$ in. dia. Worm section is driven at a speed of 2 in. per sec and stops automatically after the gear has made one turn. Charts can be analyzed to determine individual profile, spacing and tooth thickness errors. Eccentricity and departure from theoretical size can also be determined.

Fastener Has Stamped Components

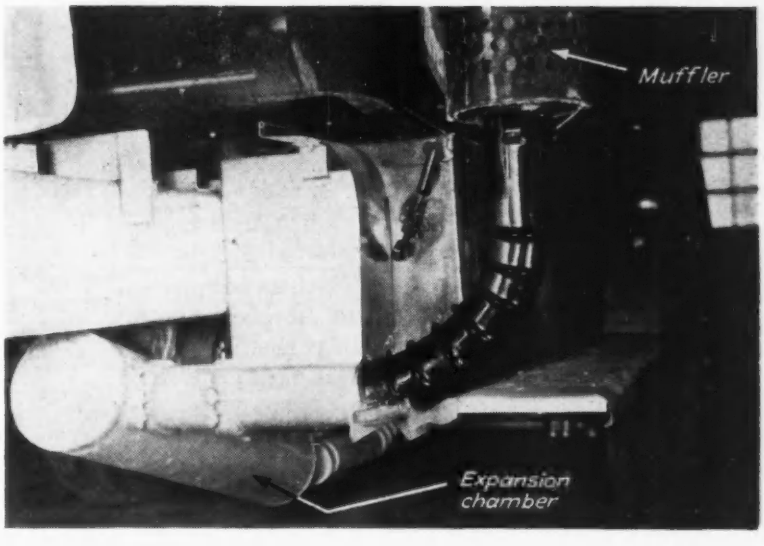
This Simmons Quick-Lock Fastener was designed to be the locking means for providing an air-tight seal on a U.S. government steel casket. The Quartermaster Corps specifications for the casket require that an absolute seal capable of withstanding an air pressure of 3 psi be made. Gasketing material is natural rubber that is compressed to a shape whereby an increase of pressure inside the casket causes the gasket fit to become tighter. Cam action fastener made by the Simmons Fastener Corporation, Albany, N. Y., is operated by a special wrench. An advantage of this type of design is that it provides a visual means of inspection to determine if the fastener is locked. The fastener in the unlocked position extends 3/32 in. beyond the casket surface. The fastener is spring loaded, thus assuring that each fastener applies approximately equal clamping pressure.

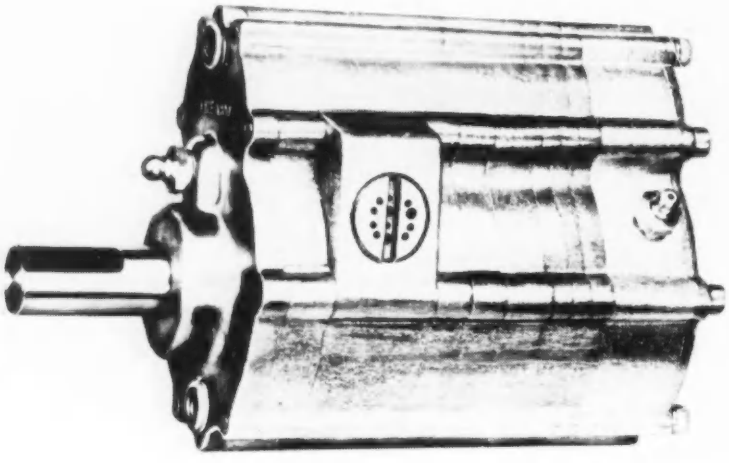


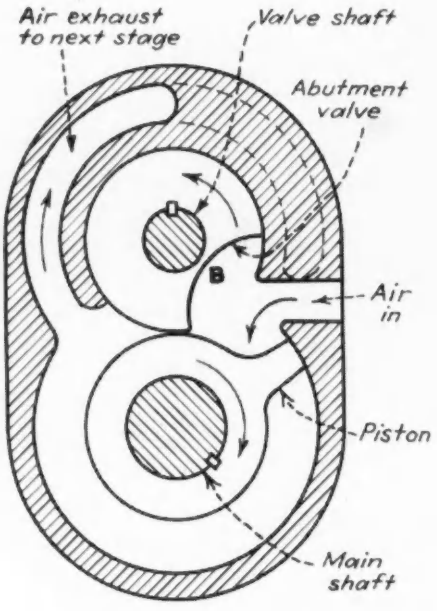
FASTENER DETAILS include both stamped and screw machine parts. The T-wrench is SAE 1020 steel bar stock, formed on a punch press. Blades are milled. Retaining ring and acetate plastic washer are produced on punch presses. Inner housing is a deep drawing steel formed in a progressive die from flat strip stock. Receptacle is a screw machine part into which is staked the stamped SAE 4130 steel insert that receives the lugs on the stud. The stud is a screw machine part that has secondary milling operations for the lugs and wrench slots.

Exhaust System Expansion Chamber

DESIGNED TO AVOID excessive exhaust noise in internal combustion truck engines, this expansion chamber can be installed between the engine and the muffler. The unit is ineffective if used in place of a tail pipe. Designed by Julius Gaussoin of Portland, Oregon, chairman of the equipment and maintenance committee of the American Trucking Association, it is merely an 8 in. dia. by 30 in. long cylindrical steel chamber. The device can be applied to either gasoline or diesel engines. In addition to reducing noise, this unit causes exhaust smoke to be shot higher in the air than in conventional installations.



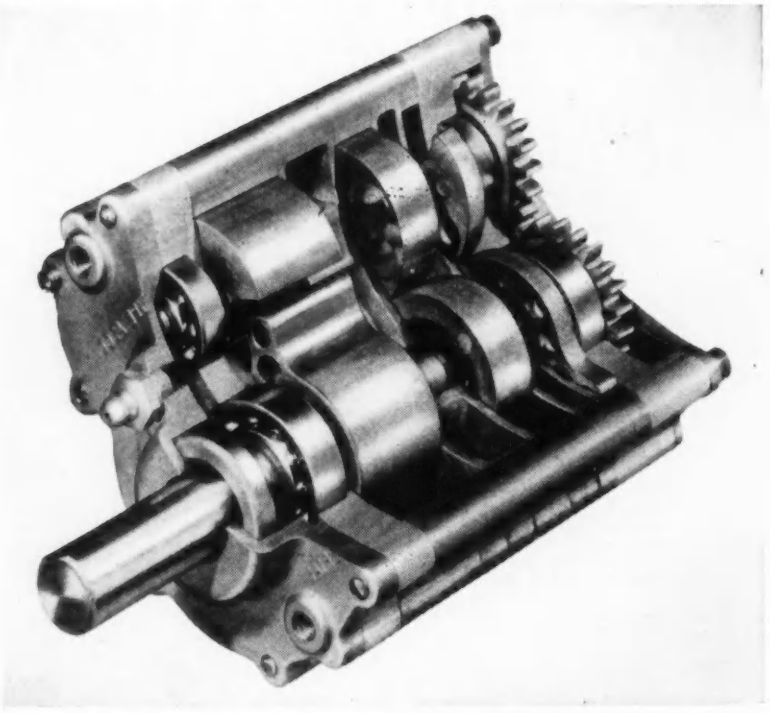




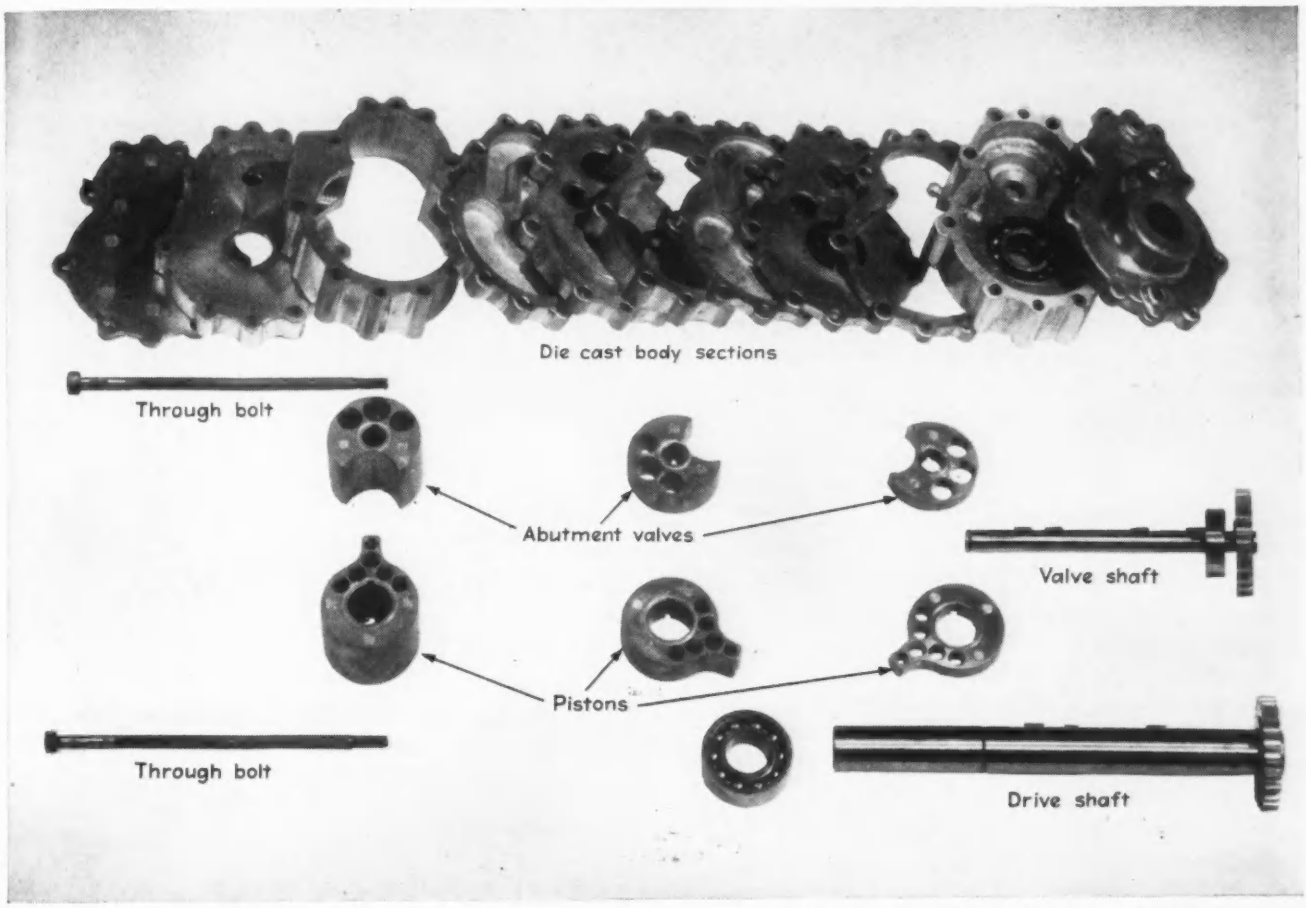
MODEL A300 air motor has three expansion stages. One of the identical stage cross-sections is shown at the right.

Lightweight Rotary Air Motor

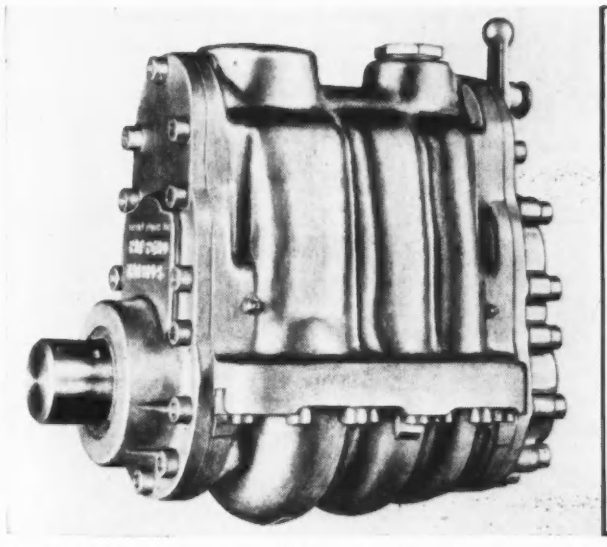
Using multiple staging and rotary piston principles, this 2 hp, 10,000 rpm, 7⅛ lb Berry air motor has a starting torque of 20 ft-lb and uses 20 cu ft of air per hp. Air enters the first stage and rotates a piston that is keyed to the main shaft. From this stage the air is directed into the next stage where it acts on a second piston, which is also keyed to the main shaft. Leakage in the pressure chambers is prevented by a rotary valve, keyed to a shaft that is gear driven by the main shaft. For industrial pressures from 90 to 150 psi, three stages are required. When using steam as a working medium, more stages are necessary. This unit can be motor driven and used as a compressor. It is 5⅛ in. long, 3 5/16 in. wide and 4 in. high. Larger models and hydraulic pumps and motors using similar operating principles are available. These units are made by Berry Motors, Inc., Corinth, Miss.

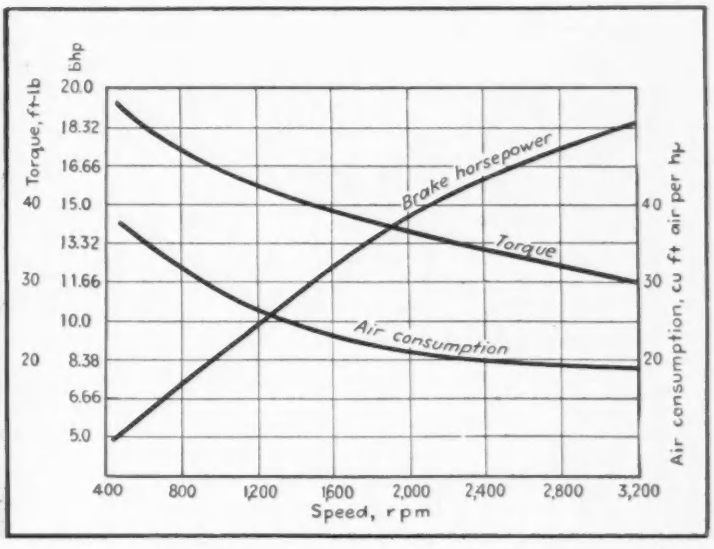


MOTOR CUTAWAY shows the three individual expansion stages. Provision for volume change is made by varying the thickness of the cylinders, pistons and valves. Valve and main shaft are drilled so that ball bearings supporting both shaft ends can be lubricated from one grease fitting. Gears are held on shafts by retaining rings. An oil seal is provided at the drive end of the main shaft. Ports, cylinders and end plates are individual die cast sections that are held together in metal-to-metal contact with eight through bolts that thread into tapped holes in one end plate. For improved efficiency and also when using contaminated air, a cast neoprene seal is included in the piston. Here, the piston is split through the flange and two screws are provided to retain the seal and clamp the piston to the main shaft. For intermittent service, plain bearings can be provided in all models.



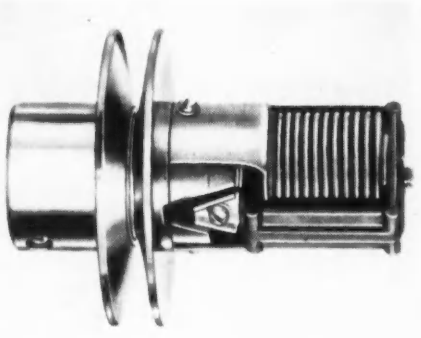
MOTOR COMPONENTS. All body sections are die cast zinc alloy as are the abutment valves, pistons and gears. Balance holes are cast in the rotating members. No machining operations are performed on the valves or pistons. Keyways are cast in proper relation with the piston so that Woodruff shaft keyways are in line. Steel shafts are ground. End wear on valves, piston and plate faces is resisted by steel washers recessed in each cylinder cover plate. Recessed holes in valves and pistons are for ejector pins. Single stage units for air compressor applications include a discharge poppet valve and a pulsator chamber. Plain bearing model has lower peak horsepower.



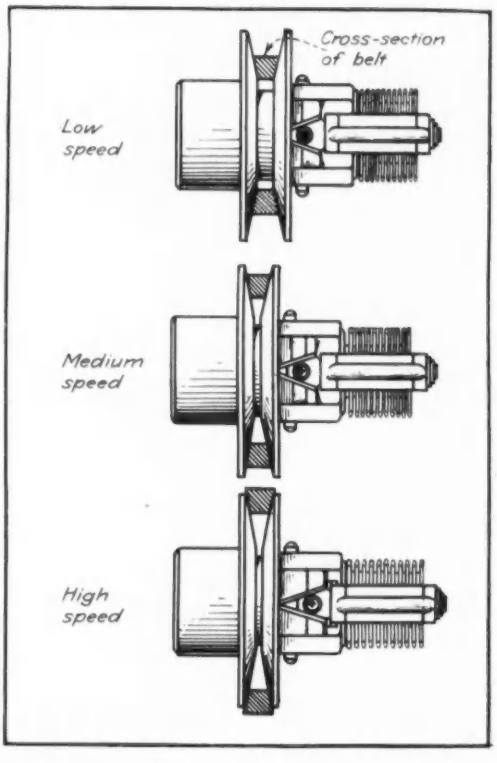


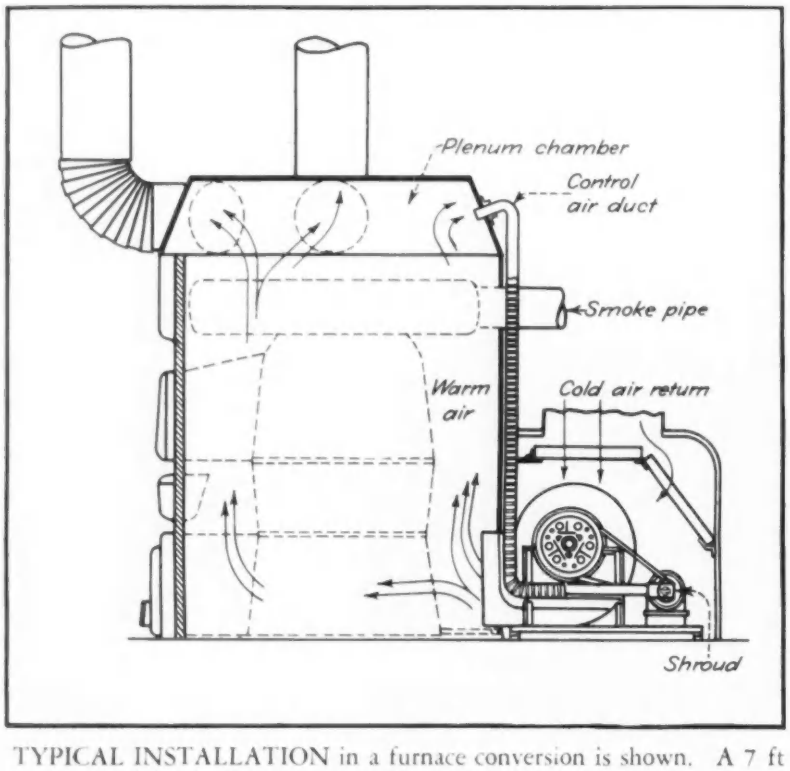
20 HP MODEL weighs 88 lb, a weight that was achieved by specifying aluminum sand castings for all body components. A reversible motor, this unit is 9¾ in. wide, 11 in. high and 16 in. long. Neoprene seals are provided in the cast aluminum pistons. Abutment valves are ground and piston hubs are shaped. The high torque available at low speeds for all of these models is evident from the performance curve shown at the right. At 3200 rpm, output is approximately 18 hp and air consumption per hp is 19 cu ft. Stalling torque is 86 ft-lb for this model.

Variable Speed Blower Control Unit

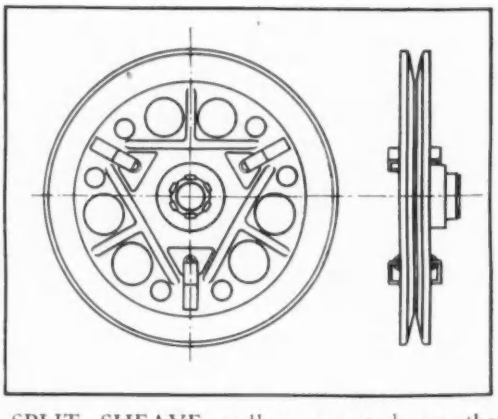


By driving the blower of home hot air furnace installations at a slow speed and increasing its speed as the bonnet temperature increases, cold air blasts are avoided. Hot overruns are avoided by slowing the blower as the unit shuts off. The Webster Electric Thermodrive unit made by the Webster Electric Co., Racine, Wis. provides such a control. The unit is mounted on the end of the blower motor drive shaft and, in conjunction with a split sheave pulley on the blower, changes speeds by changing effective pulley diameter ratios. The unit is supplied in three shaft sizes of $\frac{1}{2}$ in., $\frac{5}{8}$ in. and $\frac{3}{4}$ in. Thermodrive unit consists of a bellows that expands as the temperature of the surrounding air increases. This expansion causes the moving pulley section to approach the fixed pulley section, thus increasing the effective pulley diameter. Bellows begins to expand between 90F and 100F. Maximum expansion is at from 125F. to 140F. The two extremes in speed ratio give an air flow differential of 65 percent.



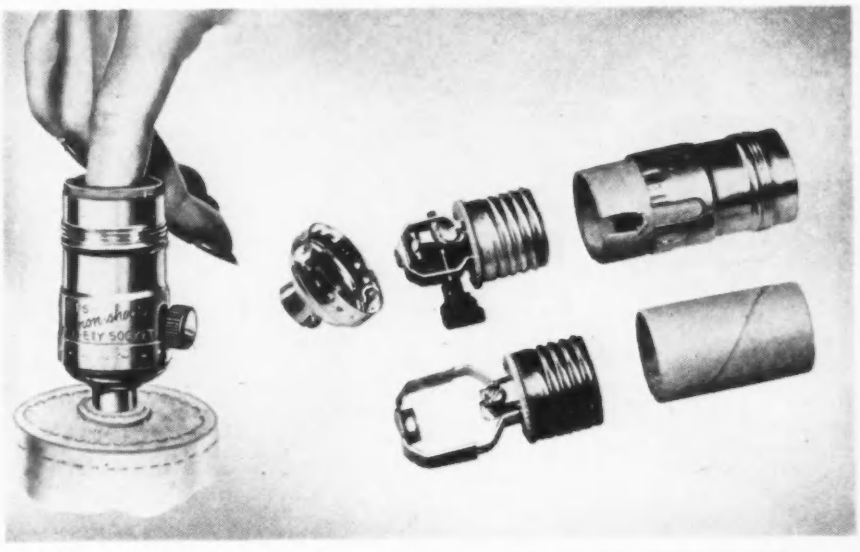


TYPICAL INSTALLATION in a furnace conversion is shown. A 7 ft length of $1\frac{1}{2}$ in. dia flexible steel tubing is provided between the plenum chamber and a shroud that incloses the thermodrive unit. The shroud is mounted so that the bellows is shielded from the return air flow. Duct attaches to the shroud with self-tapping screws. Fan control switch in bonnet should be set to cut out between 85F and 90F. "On-off" differential should be 10F. When thus installed the blower will start at slow speed and increase to a maximum. The "off" cycle is reversed and the fan decelerates to slow speed just before the motor shuts off.



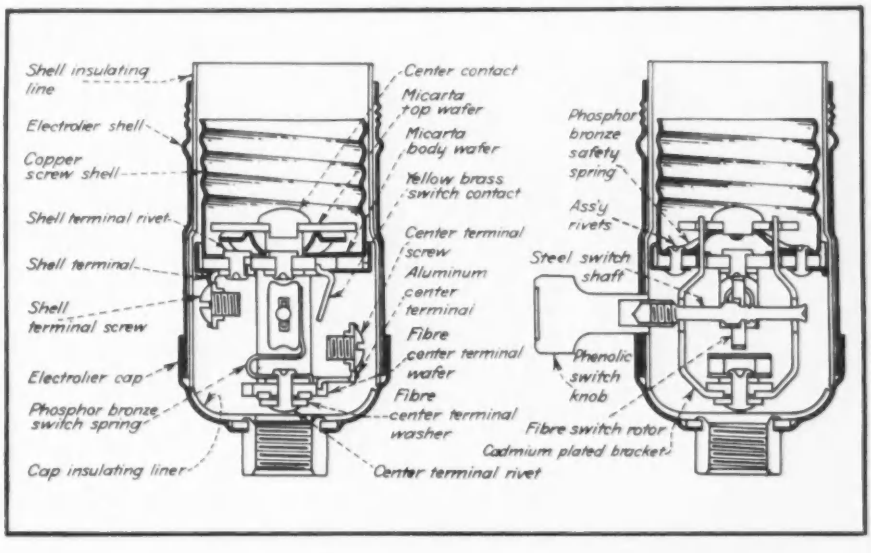
SPLIT SHEAVE pulley mounted on the blower shaft takes up belt slack as the thermodrive effective pulley diameter changes. Sheaves are held together by spring tension. Sheaves have a 1 in. dia mounting hole. Adapter bushings of $\frac{5}{8}$ in., $\frac{3}{4}$ in. and $\frac{7}{8}$ in. dia are supplied. Pulleys are provided in three sizes of 8 in., 10 in. and 12 in. dia to provide drives with different speed ratios.

Non-Shock Safety Socket



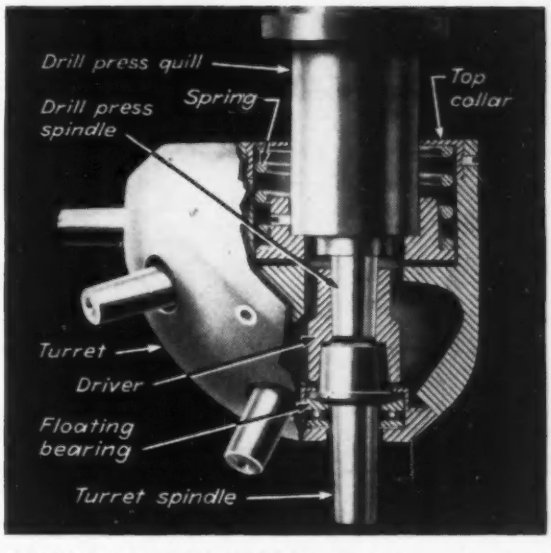
The SPS electric light socket has a design feature that prevents a person from receiving a shock when touching the bulb contact. Electrical contact is made by inserting the bulb, which causes a spring loaded contact to engage the main contact. The safety feature functions whether the socket switch is on or off. Winner of a recent Lewis and Conger Safety Award, this switch is made by the S. P. Socket Co., New York, N. Y.

SAFETY FEATURE is included in either lamp or candle type mounting. Aluminum bulb contact is mounted in an insulating wafer, which is fastened to the bracket that carries the switch. With socket empty this contact is held from contact with the main shell terminal rivet by a phosphor bronze spring. When the bulb is screwed into the socket, it advances the bracket assembly until the bulb contact touches the terminal rivet, thus making the electrical contact. Phosphor bronze switch spring is pushed into contact with switch contact by the fibre rotor mounted on the switch shaft.



Self-Aligning Drill Press Turret

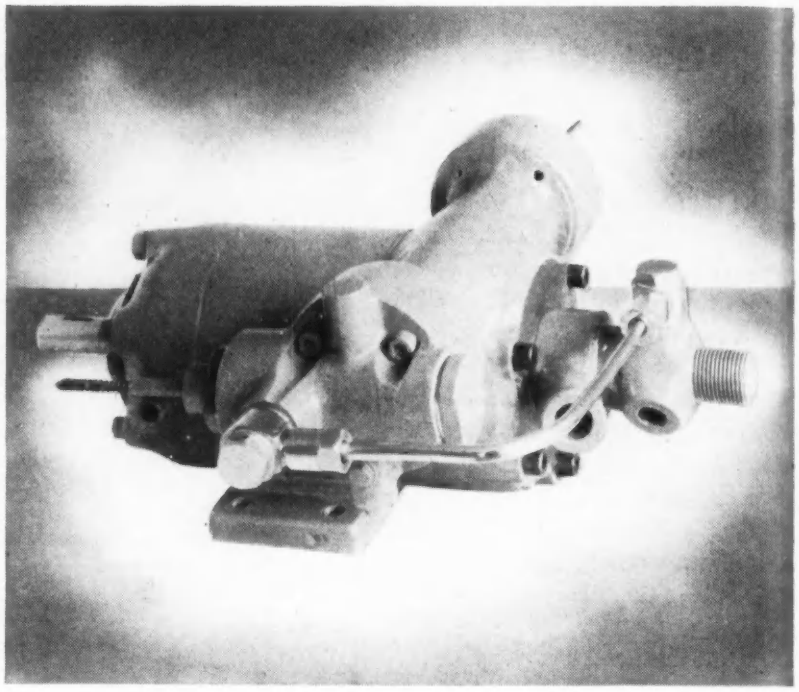
Alignment with the drill press spindle is accomplished by mounting the turret spindles on floating bearings. Lateral motion results from clearance between the turret casting and the spindle and upper bearing race. Angular motion is obtained by a convex flange on the turret spindle, bearing on a concave upper bearing race. To index, the drill press quill is raised on the top collar in the turret stops on the drill press casting. Further quill movement compresses the spring and disengages driver from turret spindle. The turret is then indexed to the next station, located by housing mark and a ball and indent guide. As the quill is lowered, the spring keeps the turret against the drill press casting until the driver engages and aligns the newly positioned turret spindle. The taper fit between the turret spindle and driver is sufficient to drive a $\frac{1}{2}$ in. drill; yet it will easily disengage. The turret is made by Howe and Fant, Inc., Norwalk, Conn.



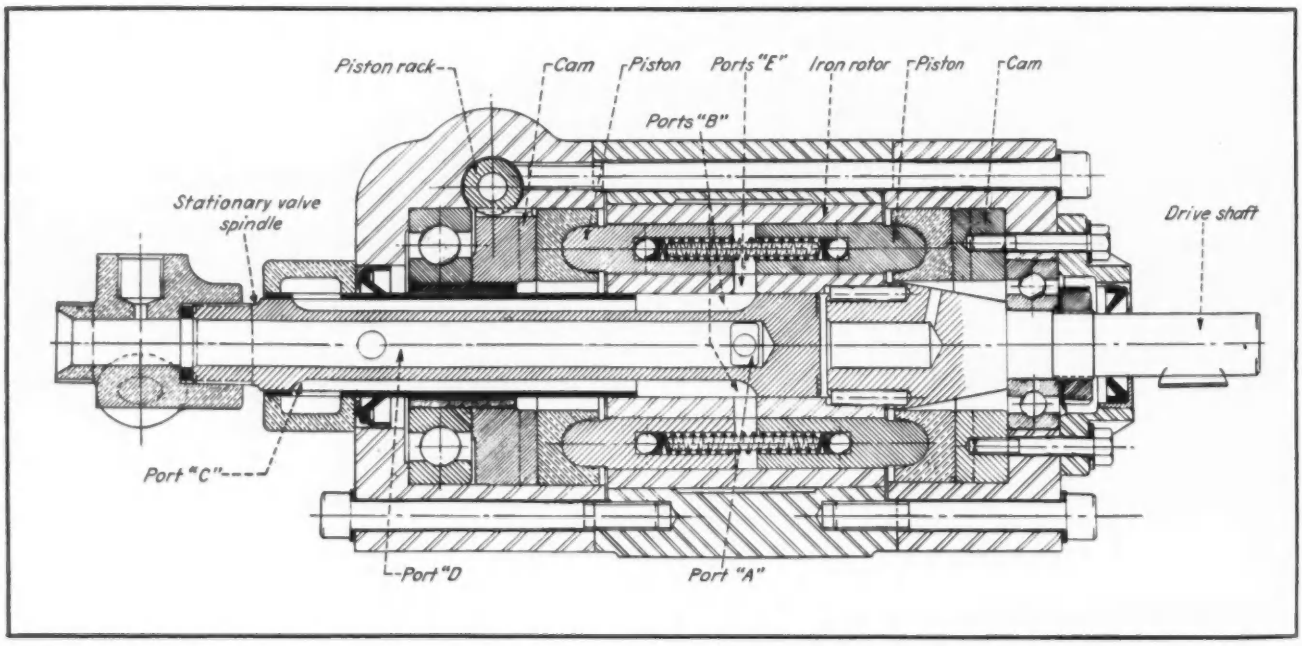
LIGN-O-MATIC TURRET weighs 7 oz. 6 oz. and is $5\frac{3}{4}$ in. dia. Housing is cast aluminum.

Compact High Pressure Hydraulic Pump

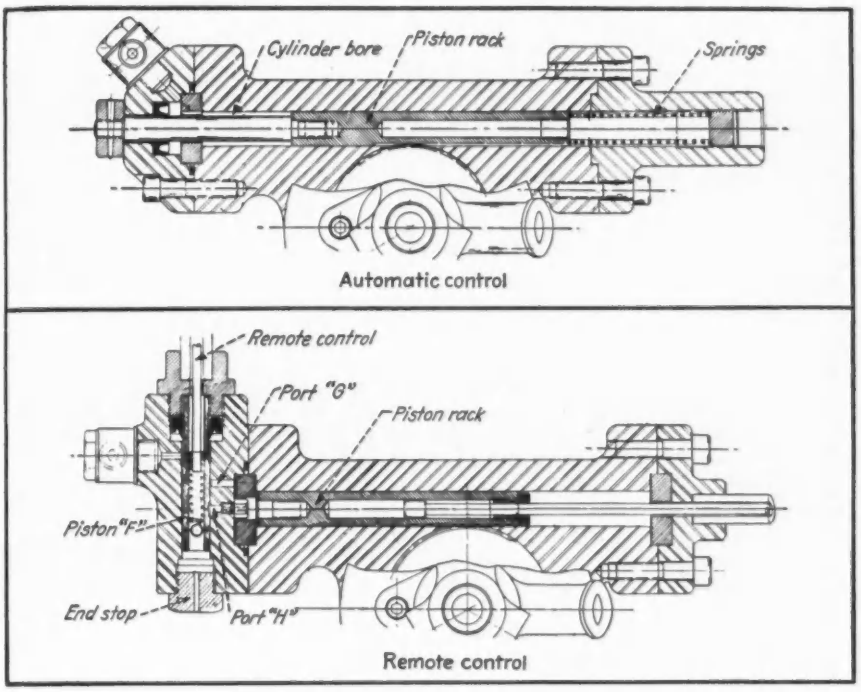
Low surface speed and high ratio of length to diameter of piston are design features that assure high efficiency over a long period of time for the operation of this variable capacity hydraulic pump. Piston speed at 1400 rpm shaft speed is 46 feet per min. Pump capacity is 7 gpm at 1430 rpm. Pressure is variable from 0 to 2000 psi. Overall efficiency at 2000 psi is 80 percent. Pump is made by L.M.L. Industries Ltd., Newport, England.



TYPE L. 500 PUMP has an overall length of 11 in. and an overall height of $5\frac{5}{8}$ in. Control of capacity and pressure can be effected by the following systems: automatic control, remote control by a flexible system, hand screw control or positive operation of the control piston by mechanical motion from the reciprocating slide or rotary table of the machine. A similar, fixed-capacity pump is made by removing capacity control parts.



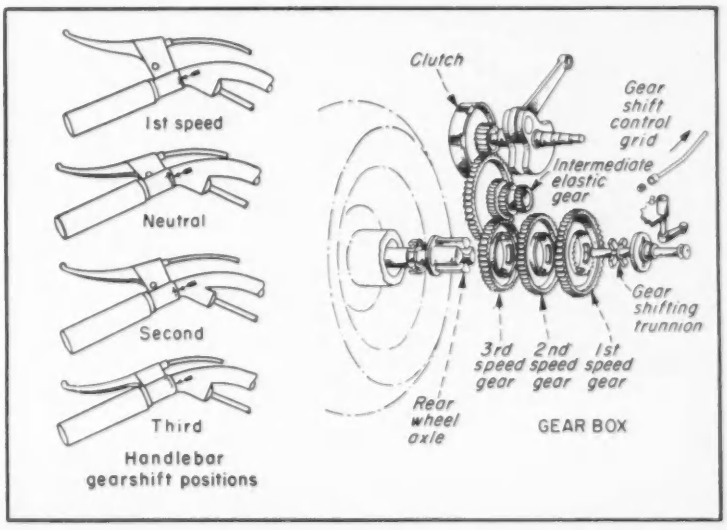
PUMP CROSS-SECTION shows the ball bearing mounted drive shaft. Cast iron rotor with a circle of axially positioned cylinder bores is rotated by the drive shaft. Each bore is fitted with two pistons that are reciprocated by cams in each end of the unit. Phosphor bronze slipper pads are placed between the pistons and cams. Each cam has a pair of diametrically opposite high points between which are diametrically opposite low points. Thus for each revolution of the rotor, each cylinder has two balanced suction and pressure cycles. Stationary valve spindle has two inlet and two delivery ports "A", and "B" (only 1 port "A" is shown) that connect with the inlet and delivery ports "C" and "D". These ports successively connect during rotation with Ports "E" in the rotor that lead to each of the cylinder bores. Right hand cam is attached to casing and left hand cam can be rotated up to 90 deg to vary the output of the pump from zero to maximum capacity by teeth meshing with piston rack.



AUTOMATIC or remote control can be provided for this pump. In the automatic control fluid from the pressure circuit is always connected with the cylinder bore and acts on the piston rack, to counteract this load and slow the movement of the rack springs that are adjustable for load conditions bear on the end of the rack. The pump delivers fluid at a constant rate until the pressure in the circuit exceeds the initial spring control setting. As soon as pressure rises above this point, the piston rack operates the left hand cam. In the remote control arrangement, the fluid in the pressure circuit connects with spring loaded piston "F". When fluid pressure exceeds cutoff pressure, piston moves to the end stop and permits fluid to pass through port "G" and exert pressure on the piston rack. As pressure is reduced, piston "F" closes port "G" and opens port "H" and piston rack returns to the capacity setting.

Motorcycle has Stamped Frame

One of the lightweight features of this rear engined "Vespa" motorcycle is a stamped sheet steel frame with a wide steel apron that acts as a windbreaker. Powered by a 4 hp 4500 rpm engine, the vehicle has a top speed of 43½ mph. Gasoline consumption is 106 miles per gallon at 30 mph. Engine has cast aluminum alloy cylinder head, crankcase and piston. Plate-type clutch has cork inserts. Wheels are stamped with an integral brake drum. Engine and rear wheel form a single unit that is flexibly mounted on the main frame. Motorcycle is made by the Piaggo Co., Genoa, Italy. Empty weight is 132 pounds.



GEARSHIFT CONTROL and clutch control are located on the left hand side of the handlebar. Shift control is operated the same as the throttle control on a conventional motorcycle. Numbers on the handle grip identify the individual shift positions. To shift gears, the clutch lever is pulled and the handle turned to the desired position. Clutch control lever is then released slowly. The gears can be shifted without using the clutch, according to the maker.

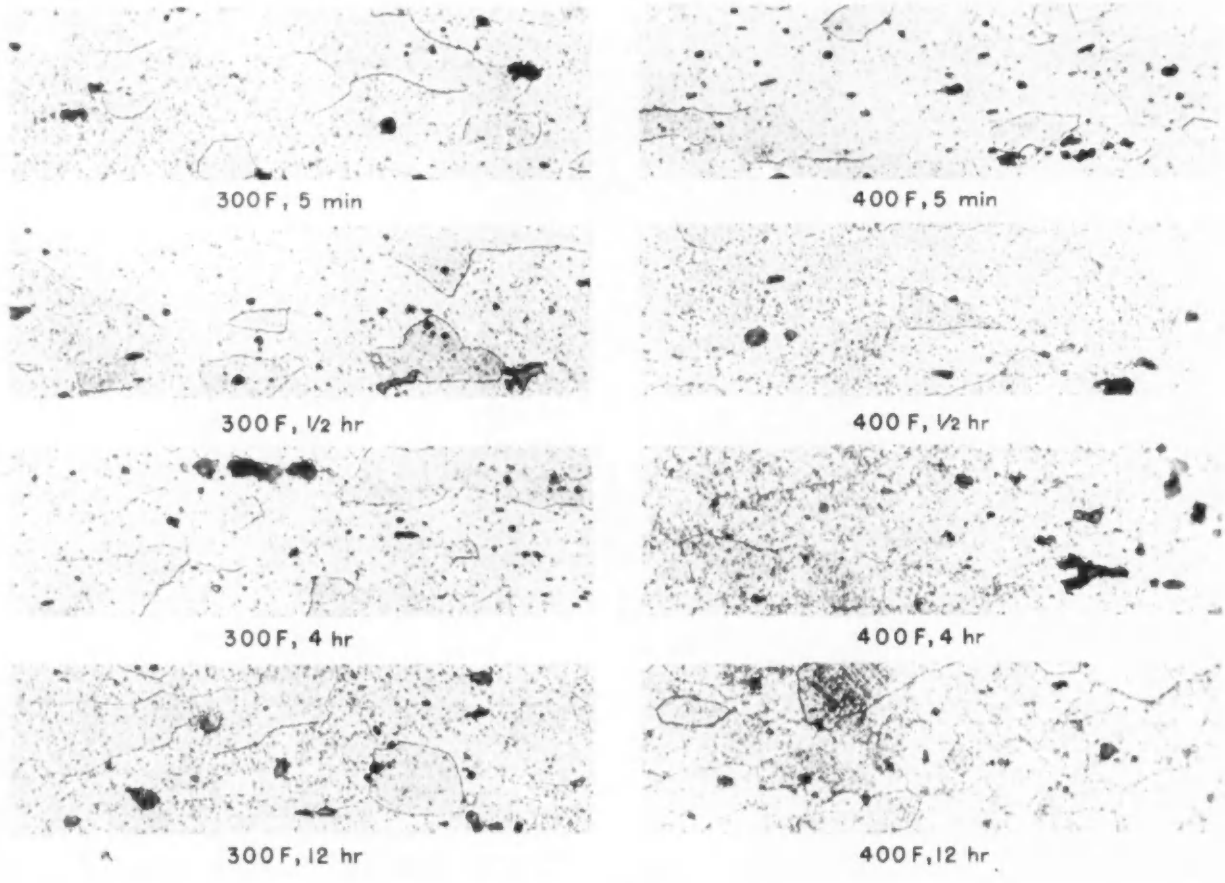


Fig. 1—Effect of heating at 300 and 400 F on the microstructure of 24S-T sheet. All micrographs shown at 500X initial magnification.

Effects of Overheating Aluminum

P. A. HAYTHORNE and H. B. WILEY
Research Engineers, Lockheed Aircraft Corporation

Method whereby the structural properties of aluminum suspected to be impaired from accidental exposure to heat can be appraised from color changes in zinc chromate coated surfaces.

FREQUENTLY it is necessary or desirable to determine the extent of damage sustained by structural aircraft components when exposed to sources of over-heating. Exposure to accidental fires, impingement of hot gases, or transfer of heat from nearby assemblies raises the question "How much has the strength and corrosion resistance properties of the structures been impaired?"

The soundness of skin, rib, bulkhead and stringer structures, as well as members of wing sections, fuselages, and engine nacelles have often been questioned after such parts have been exposed to heat.

Without resort to destructive testing, no satisfactory criteria have been available for establishing whether a suspected structure should be replaced or accepted for further service.

In the absence of suitable non-destructive tests some perfectly intact and metallurgically sound structures, which were only believed to be damaged by overheating, have been unnecessarily rejected and replaced with new structure. At other times damaged components have remained in service in non-critical applications.

In an effort to determine the degree of damage sustained by overheated aluminum aircraft structures, the Lockheed Metallurgical Research Laboratories have devised an appraisal method based on color modification occurring in zinc chromate surfaces when subjected to heat. This method has been adopted for use by field service and reclamation groups.

Investigations show that the temperatures attained by structures coated with standard zinc chromate primer can be determined, with reasonable accuracy, by a study of the color modifications that occur during service. Two sets of aluminum 24S-T specimens, therefore, were prepared. One set was coated with yellow zinc chromate primer, Specification AN-P-656. The other set was coated with zinc chromate primer pigmented to the dark green color No. AN-A-611. These shades are standard at Lockheed.

Under carefully controlled laboratory conditions, these coated specimens were heated to temperatures of 300; 400; 500; and 600 F for time intervals of 5 min, $\frac{1}{2}$, 4 and 12 hours.

With increase in time and temperature the yellow coating becomes progressively orange, tan, brown and in 4 to 12 hr at 600 F it becomes gray-green. The dark green primer, with increase in time and temperature,

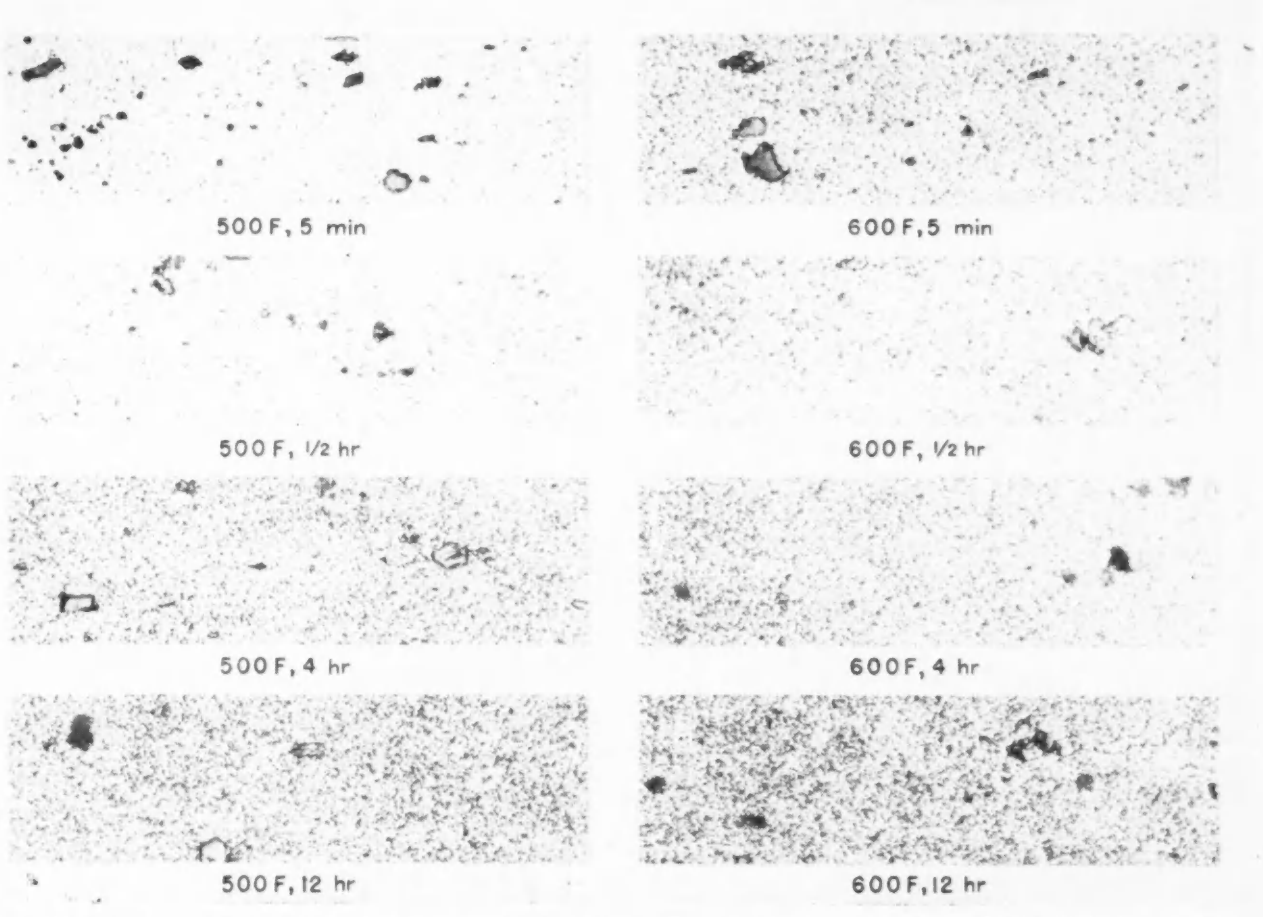


Fig. 2—Effect of heating at 500 and 600 F on the microstructure of 24S-T sheet. All micrographs shown at 500X initial magnification.

Determined by Color of Coating

progresses rather abruptly to dark brown and finally to the same shade of gray-green in 4 to 12 hr at 600 F.

The gray-green color is ascribed to the decomposition of pigmenting materials. The powdery consistency and flakiness of the coating at this stage of paint deterioration makes it easy to differentiate from similar colors occuring at lower temperatures. By comparing and matching the color of a skin or structural component, which has been exposed to heat, with the colors of the prepared laboratory specimens, the engineer can identify both the temperature and length of time of exposure to heat suffered by the part being examined.

Further work was done in the laboratory to correlate paint coating color changes with variations in strength and microstructure caused by heating 24S-T Alclad sheet. Core materials were heated to the same range of temperatures and time intervals as those to which the coated specimens had been exposed. The treated core materials were then tested for hardness. The results of these tests are given in the accompanying table. These data are essentially for purposes of comparison. Micrographs of treated core materials were made to study the modifications in microstructure.

The effects of heating treatments on the microstructure of 24S-T core alloy are shown in Figs. 1 and 2. The 300 and 400 F treatments with exposure for 5 min are without visible effect on structure of properties. Progressively increasing precipitation is apparent after 400 F treatments for ½, 4 and 12 hr. Initially this precipitation lessens grain contrast and diminishes grain boundary resolution. Finally heavy precipitation occurs throughout matrix grains and at boundaries. The partial agglomeration of constituents and the complete absence of grain boundary delineation resulting from the 500 and 600 F treatments are indicative of the approach to the annealed state.

There may be some question as to what extent the effects of heating may be tolerated. But it is generally conceded that overaging of the material at 400 F will decrease corrosion resistance. The softening, of course, that occurs at higher temperatures will render the alloy structurally unsound.

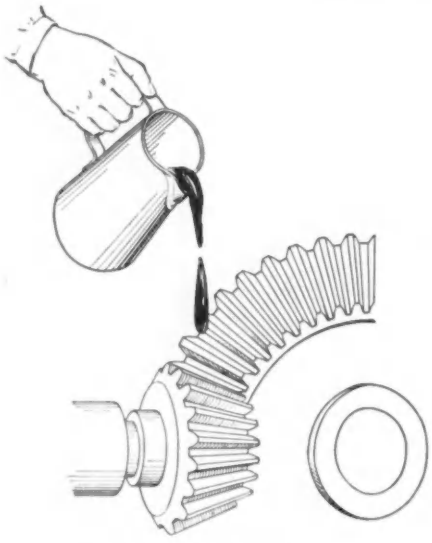
In accepting or rejecting assemblies previously subjected to elevated temperatures in service, therefore, it is recommended that: (1) Color comparisons be made with unaffected structure (showing original paint pigmentation), and (2) Those parts that show indications of heating to 400F and higher temperatures should be replaced in critical applications.

Superficial Hardness, Rockwell 15N, Of Treated 24S-T Alclad Sheet

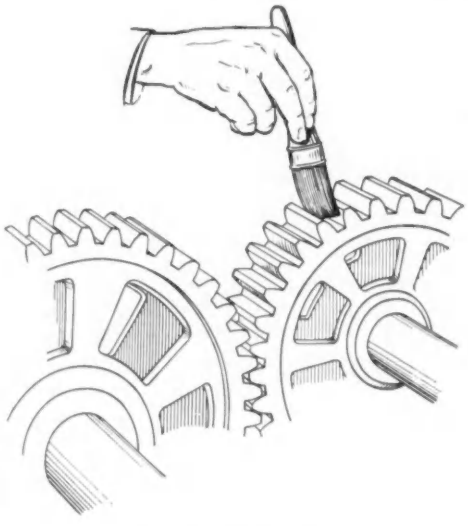
Temp. F	Treatment Time, Hours			
	1/12	1/2	4	12
300	53	52	52	51
400	50	51	54	53
500	53	52	45	43
600	49	45	38	31

Typical Methods of Providin

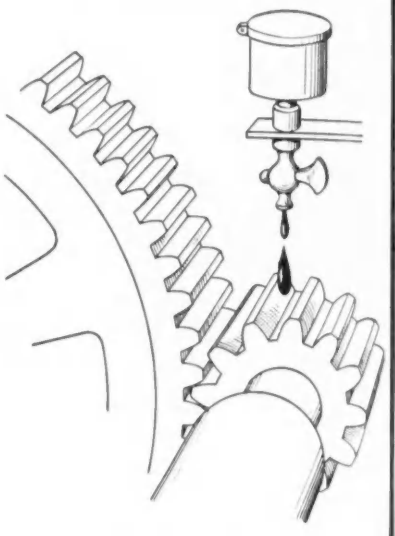
Below are shown various lubricating systems that can serve as gui



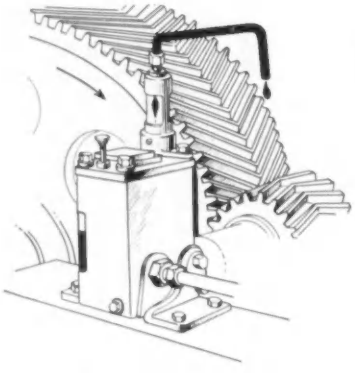
CAN APPLICATION



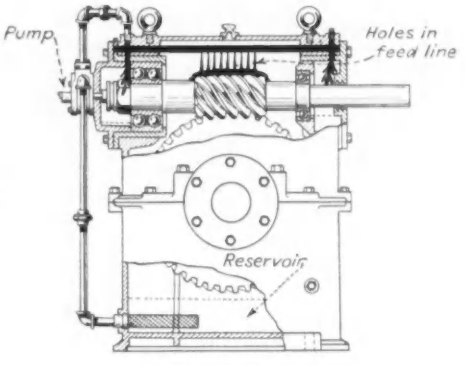
BRUSH APPLICATION



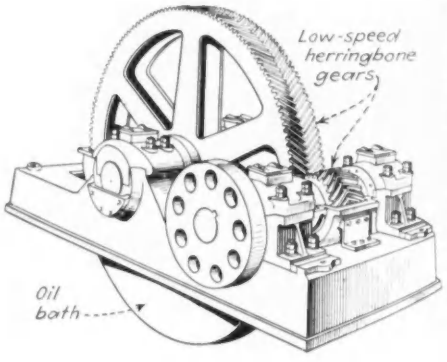
DRIP OILING



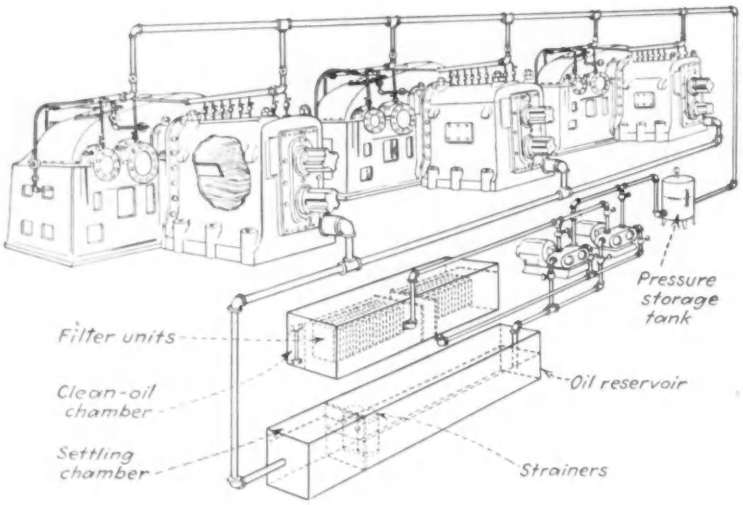
FORCE-FEED LUBRICATION



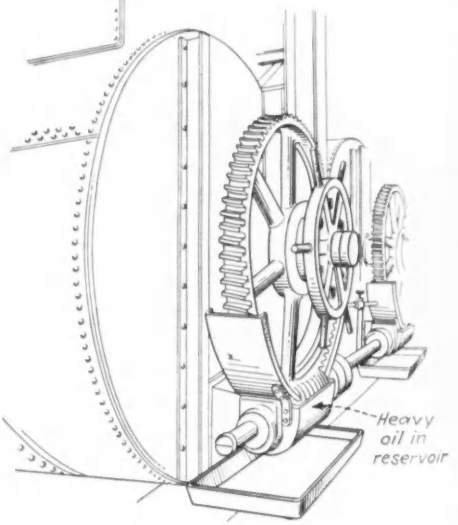
WORM GEAR SET



OPEN GEAR



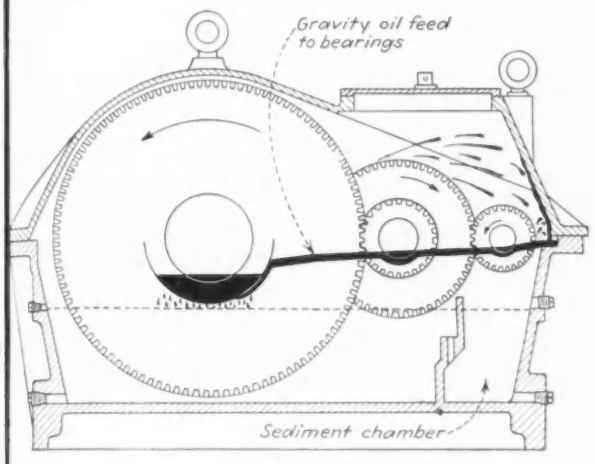
CENTRAL OILING SYSTEM



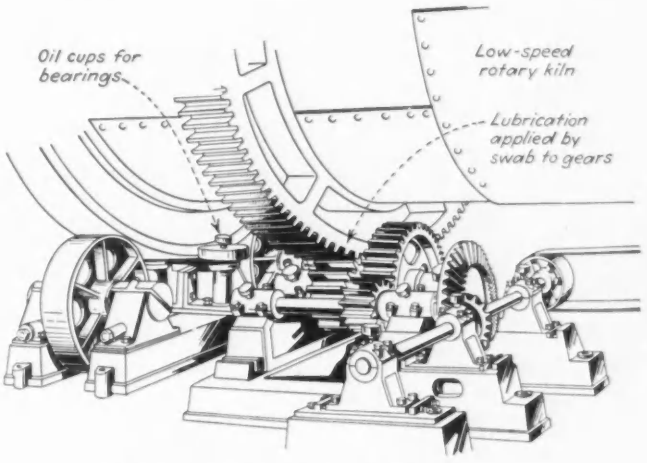
OPEN WORM GEARS

ubrication for Gear Systems

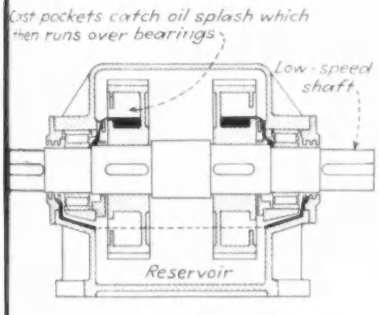
gui designing for successful, efficient gear systems.



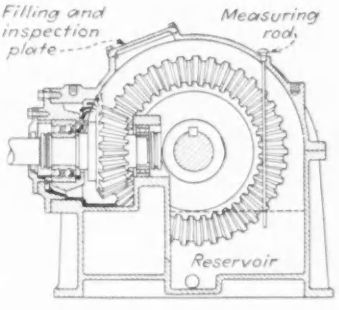
SPLASH SYSTEM



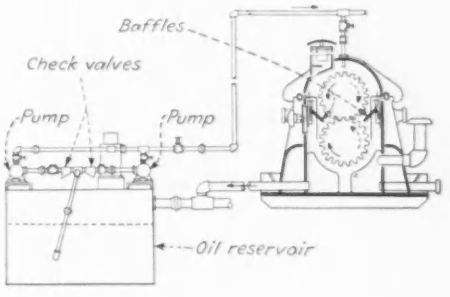
OPEN BEVEL AND SPUR REDUCTION GEARS



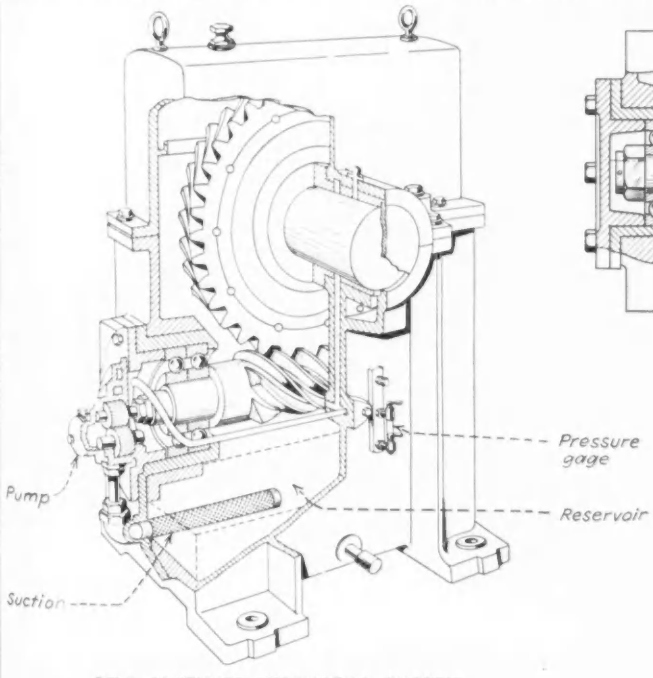
SPLASH-LUBRICATED GEARS



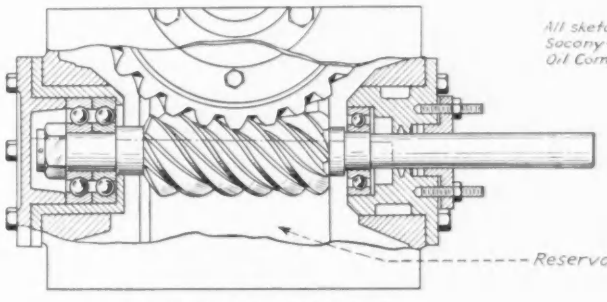
DIRECT PLASH LUBRICATION



LUBRICATION FOR BOTH DIRECTIONS

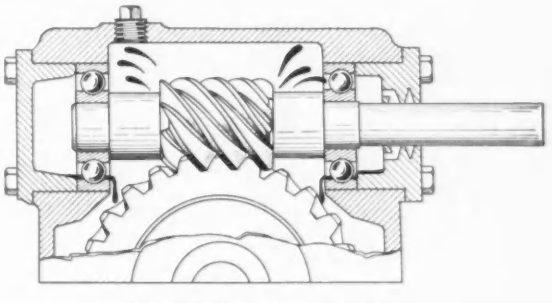


SELF-CONTAINED LUBRICATION SYSTEM



All sketches courtesy Socony-Vacuum Oil Company, Inc.

UNDER-DRIVEN WORM SET



OVER-DRIVEN WORM SET

Backlash Considerations When Designing Gears

Factors affecting backlash in gears and importance to be attached to each when designing. Cost of backlash, and methods for determining amount needed and amount obtained. Designs that produce zero backlash in gears for specific installations.

LOUIS D. MARTIN
Gear Engineer
Eastman Kodak Company, Camera Works

BACKLASH IN GEARS is the play between mating gear teeth. It is important to emphasize the word mating. Backlash results in an angular displacement when one gear is fixed and the other is rotated. The amount of play varies slightly, all other things being equal, with the number of teeth in the arc of engagement.

Backlash has been defined by the AGMA Nomenclature Committee as: "The Amount by which the width of a tooth space exceeds the thickness of the engaging tooth on the pitch circles". This definition is prefaced by a caution note "for the purpose of measurement and calculation". Obviously, as indicated in Fig. 1, this definition applies to a single pair of engaging teeth when the gears are mounted in their final assembly.

The influence of factors other than tooth thickness on the backlash of gears in their final mountings cannot be included in a general definition. The following are some of these factors that govern backlash of gears on their final mountings: Variation in gear centers; excessive play between journals and shafts; excessive runout in anti-friction bearings, and composite tooth errors in gears.

INFLUENCE OF COMPOSITE ERROR

Backlash in a pair of gears is influenced by the composite tooth error. This error is made up of the following: Runout; pitch error; tooth thickness variation; profile error and lateral runout or wobble.

When two mating gears are rotated on their centers, backlash through their arc of action changes in amount. The degree of change is dependent on the presence of any or all of the five errors listed above. Runout, for instance, causes a uniform increase and decrease in backlash in a pair of gears of equal ratio. Runout describes a true sine wave. The sine wave characteristic is sometimes used to advantage in a pair of gears of equal ratio, such as miter bevels, to obtain uniform backlash. In such cases the high spot of the runout of one gear is matched to the low spot of the runout of its mate. While this evens the backlash, it does not improve the irregular angular motion caused by runout.

Pitch error, tooth thickness variation and profile error all tend, in varying degrees, to change the amount of backlash in a pair of gears. The composite tooth error when combined with runout, as in Fig. 2, is called the "total composite error".

There are several conceptions of backlash which can be classified as follows: 1. Backlash produced in the individual gear considered as one tooth of a gear being thinner than the space between teeth of the mating gear. 2. Composite backlash; the backlash through the arc of action in a pair of mating gears running together and including the effect of composite tooth errors. It does not include the effect of errors in mounting the gears or in the gear housing. 3. Assembled backlash. This is the actual backlash in a pair of mating gears in their final assembly and includes the effect of the errors in the gears themselves, the gear centers and bearings.

WHY BACKLASH IS NECESSARY

Backlash is necessary to prevent gears from jamming together and making contact on both sides of their teeth simultaneously. Lack of backlash usually contributes to noise, overloading and over-heating of gears and bearings. Seizure and failure in may gear applications may be traced to insufficient backlash. Room for lubrication must be provided for proper gear operation. Lacking this, the oil can be trapped at the root of the teeth. This inevitably results in over heating and excessive tooth loading. In gears that operate at elevated temperatures, the backlash must be enough to still leave room for the lubricating film after the gears have expanded. This is an important consideration when the gears run hotter than the housing in which they are mounted, and thereby expand more than the housing section between the shafts. The heat can result from a number of causes: (a) Heat transferred from external sources such as an engine or motor attached to the gear box; (b) churning oil; (c) frictional losses between

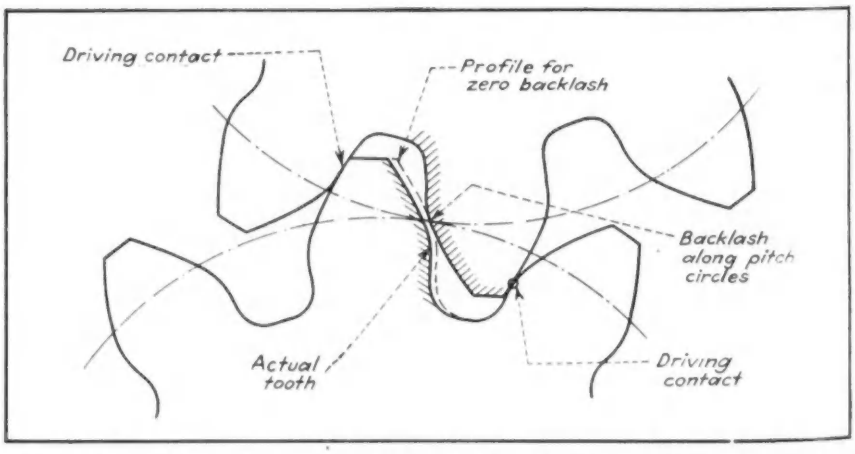


Fig. 1—Blacklash between tooth profiles as indicated by AGMA Nomenclature Committee definition. Dashed line shows theoretical profile for zero backlash.

teeth; and (d) bearing or oil seal friction.

Frequently, gears are made of material different from that of the housing. An example of this is found in worm gearing. The worm gear is usually made of bronze, the mating worm of steel and the gear housing is invariably made of iron. Consideration must therefore be given to the differential in heat expansion of the several components when determining backlash in assembly.

Backlash beyond the amount necessary to prevent gear teeth from jamming together, plus enough to allow sufficient clearance for lubrication and to compensate for thermal changes can be considered as excessive. In many applications, excessive backlash is a direct cause of failure, particularly if the device is frequently reversed, or if there is an over-running load. Certain types of cam drives and rapidly reciprocating parts which cannot be properly dynamically balanced are liable to cause failure in gears with excessive backlash. Excessive backlash, which is obtained by cutting thinner teeth either by side cutting or cutting deeper than standard, results in weakened teeth.

No definite rule can be given for the proper amount of backlash for gear sets. Fundamental facts should be kept in mind and each application studied separately. A suitable amount of backlash for one application may be too much for another. Pitch and relative size of gears must be considered. The finer the pitch, the greater the proportional amount of backlash that can be tolerated. Some rational relationship between tooth thickness and backlash must be maintained. As an example, consider a 100 pitch gear with a tooth thickness of 0.0157 inches. Ten percent of the tooth thickness, or 0.0016 in., would be a generous allowance for backlash in gears with this pitch. If the gear were 10 pitch its tooth thickness would be 0.1571 inches. On the same basis of ten percent, 0.0157 in. would be the backlash allowance. It is evident that this amount is too much. However, the 100 pitch gears may be used in a mechanism that does not require the same allowance for lubrication, thermal changes and tooth interferences as required for the 10 pitch gears.

Relative load carrying capacities must be considered. What, then, is the yardstick for the proper amount of backlash? Wherever backlash can be tolerated, and there are exceptions which will be dealt with later, use as much as possible but be sure the following fundamentals have been given proper consideration: 1. Tooth strength. Backlash can be obtained in many cases by changing center distance without thinning the gear teeth. 2. Allowance for thermal changes. 3. Allowance for lubricating film. 4. Allowance for total composite error in gear teeth.

To offer a guide for the correct amount of backlash to use for gears of various pitches, a backlash curve has been developed. This curve, Fig. 3, is based on the average amount of backlash found in gears for the pitch range given. A field research was made covering backlash cut in gears used in several hundred different devices. This study extended over a period of several years and yielded a fair cross-section of gears in common usage operating under average conditions. When the backlash given in Fig. 3 was put in terms of tooth thickness reduction in each gear and proper allowances were made for special gear applications, a straight line curve shown in Fig. 4 resulted.

It is interesting to note that this curve follows closely the average backlash specified for fine-pitch gears in Section 5 of AGMA Standard 236.01. In gears of 30 D.P., and coarser, it is considerably more liberal than ASA Standard B6 6-1946.

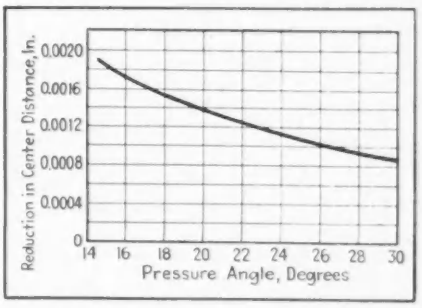


Fig. 3—Backlash curve of gears with 5 to 100 D.P., based on field research over several years, gives average backlash in each gear for sets operating under normal thermal variations. Backlash in the pair is twice amount shown.

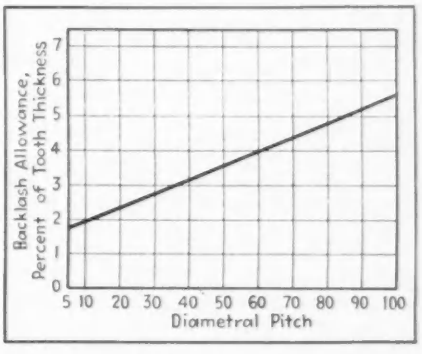


Fig. 4—Backlash allowance curve for each gear in percentage of tooth thickness.

Assuring Proper Backlash

There are several ways of obtaining the proper amount of backlash in assembly. The method most generally used and which fits best into mass production methods, consists of controlling every production phase of the gears, gear components and housings. It might be broken down into the following steps: Control of gear cutting and finishing within specified limits, including all steps of gear manufacture from raw material to finished gear; control of boring the gear centers and housing bores to a tolerance compatible to the backlash desired in assembly; maintenance of the proper clearances between shafts and journals, and guarding against additional runout by not using anti-friction bearings that have excessive eccentricity.

A second method of obtaining proper backlash in assembly is to use adjustable centers. When this technique is used, gear centers may vary from the standard center distance by

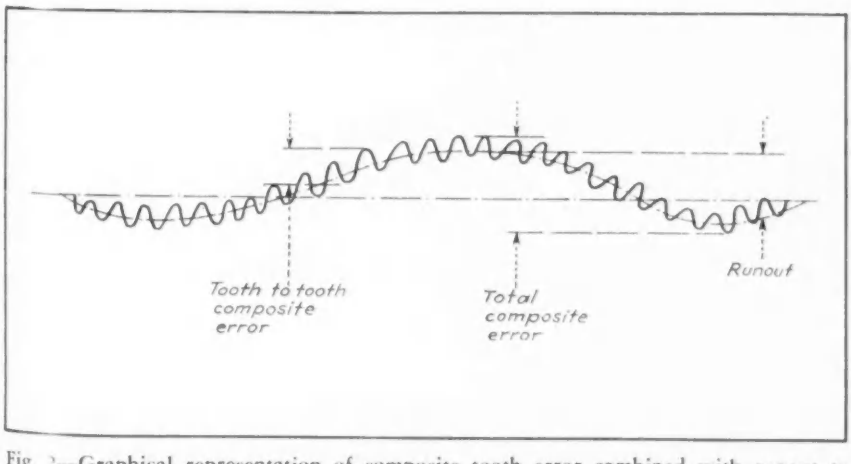


Fig. 2—Graphical representation of composite tooth error combined with runout to form "total composite error". Shows how backlash can vary during revolution.

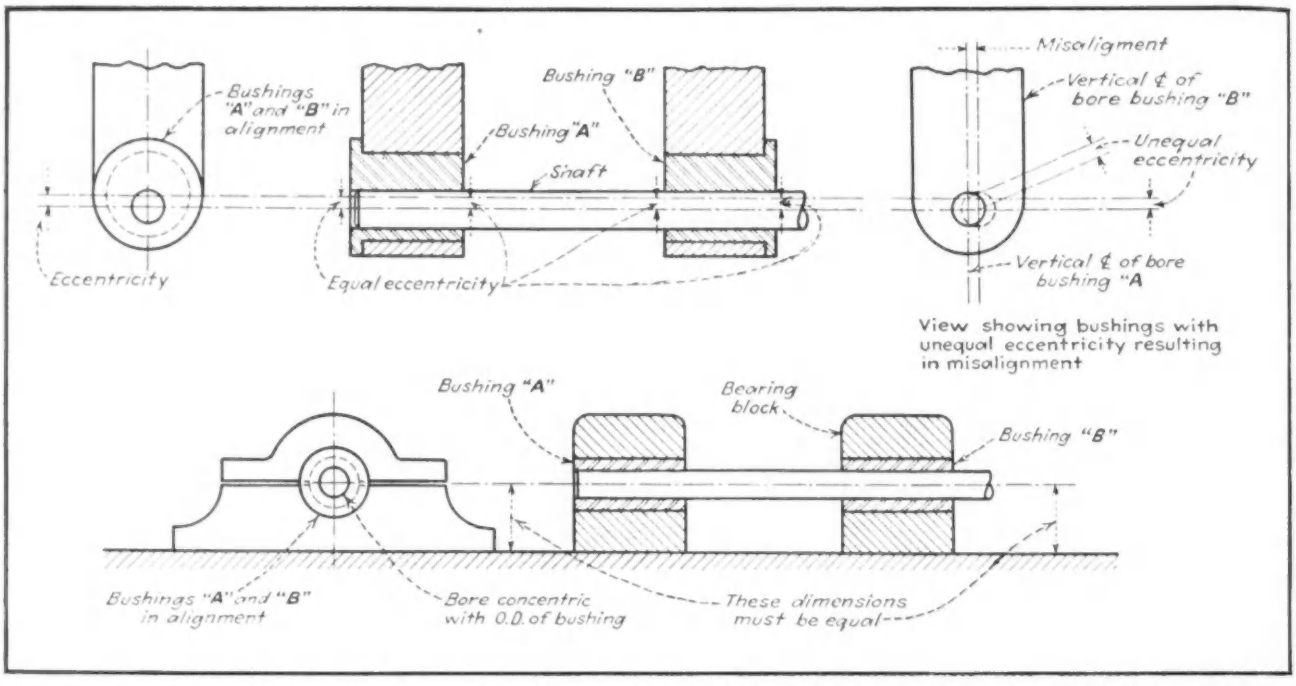


Fig. 5—Conditions for correct and incorrect alignment in eccentric bearings and bearing blocks are considered with backlash.

an amount equal to the adjustment that has been provided. Alignment accuracy, however, cannot be relaxed, for while eccentric or floating bearings may permit center distance to change they do not correct misalignment. The contrary is often true. This procedure does not lend itself to mass production and finds its chief use in instruments, machine tools and heavy equipment. In many of these applications, a minimum amount of backlash is required and often provisions are made for backlash adjustments in service. Most of this equipment is custom built or made in relatively small quantities. Ratios of assembly costs to part costs are considerably different in goods of this type than they are in items like automobile transmissions, where parts must fall together. Following are some of the advantages and disadvantages of adjustable center installations.

ADVANTAGES: 1. Gears can be cut with greater tolerances for tooth thickness since they can be allowed to vary in a plus as well as a minus direction. If the teeth are made thicker than standard they will have greater strength than those that have been cut thinner than standard to allow for backlash. 2. Gear centers can be allowed to vary in a plus or minus direction from the standard center distance. 3. The desired backlash can be obtained by adjustment in assembly. 4. Provides for backlash adjustment in service.

DISADVANTAGES: 1. This method is slow and costly. 2. It does not lend itself to mass production. 3. Adjustable centers cannot be conveniently used in devices where field replacements are required. They require individual adjustment with special aligning devices and hooks to hold the bearings in place. When worn gears are replaced by new gears, changes in adjustment may be required. 4. When eccentric bushings are used, the same amount of eccentricity must be maintained in bushings assembled on the same shaft. If this is neglected, misalignment will occur. It is also necessary to hold the eccentricity constant along the axis of the same bushing, otherwise the shaft will be sprung and cause binding. When bearing blocks are used, as in Fig. 5, the distance from the center of the bore to the base must be maintained or misalignment will take place as with bushings of different amount of eccentricity.

While these observations may seem elementary, their importance cannot be minimized. In service, many gear failures have been traced to flagrant disregard of these fundamental principles.

Bevel gears of all types generally lend themselves to backlash adjustment in assembly. Their mounting distance can be altered to some extent without affecting tooth bearing. This is particularly true of spiral, bevel gears, and hypoid gears in which some accommodation for backlash exists. It should be emphasized that particular attention must be given to guard against changes in tooth bearing when backlash adjustments are made.

Worm gearing also is amenable to backlash adjustment in assembly. These gears are extremely sensitive to small changes in center distance, and resulting change in tooth bearing especially when high lead angles are used. A small amount of misalignment between worm axis and gear axis causes disturbances in tooth bearing. Worm gears of high lead angle and large contact ratio are the most sensitive to alignment changes.

Selective assembly is a third method for controlling backlash during assembly. This procedure is more common than might be supposed. While gears are matched primarily to obtain best tooth bearing, some companies also grade gears for size. Grading for size was used extensively in many fire control devices made during the last war. It can be applied where gear components are replaced as units.

Zero Backlash Gears

So-called zero backlash gears are gears that are so perfect in regard to size and composite error that they can operate metal-to-metal with no measurable backlash. Zero backlash applications invariably require a very high degree of accuracy since the transmission of uniform angular motion is very important. In involute gears backlash has nothing to do with gear quality and its presence or absence does not affect the uniformity of motion. However, it cannot be completely eliminated without, at the same time, doing away with all other gear teeth errors. Gears having any of the five

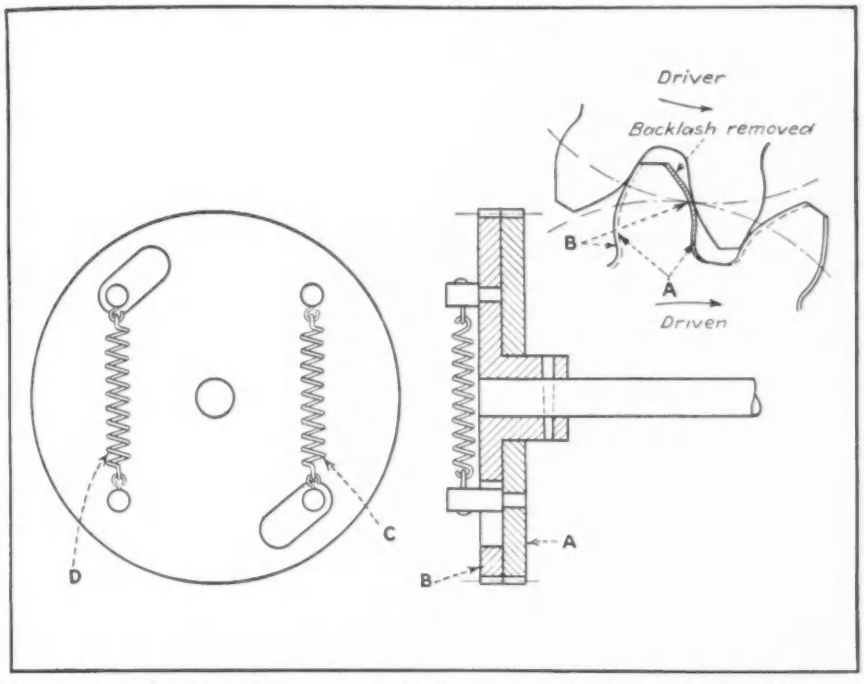


Fig. 6—Typical method of removing backlash in gears by spring loading double gears.

errors that are included in the composite error cannot operate without some backlash. Since true perfection is an ideal and even the best gears cannot be perfect, it would seem physically impossible to produce zero backlash gears. Metal-to-metal gear applications, nevertheless, can and have been made (See PRODUCT ENGINEERING, July 1947, page 150). The composite error, however, is so minute that it is integrated over the number of teeth in the arc of action. The more teeth in engagement the greater composite error can be tolerated without producing measurable change in backlash in final assembly. This is one of the reasons why fine-pitch gears are desirable where uniformity of motion is extremely important.

Devices, such as the one shown in Fig. 6, while very ingenious do not offer a practical solution to zero backlash gears because, while they do avoid play between the teeth, they do not improve the transmission of uniform angular motion. A greater bearing load is imposed because, to be effective, springs "C" and "D" must have a combined force somewhat greater than the transmitted load. Also the floating gear "A" does not contribute to the load carrying capacity since it contacts the non-driving side of the tooth and serves merely to take up the backlash. Because there is composite error in the teeth the floating gear "A" must be resiliently mounted, hence the need for springs. A better way of taking up backlash in metal-to-metal applications is by means of tapered gears. These gears, shown in Fig. 7, are true involute gears made with either spur or helical teeth and are cut with a small amount of taper. When displaced on their axes, one to the other, they can be made to take up backlash. Again, in gears of this type, the composite error must be reduced to nothing in order to operate without backlash. In the production of gears of this type, consideration must be made for the changes that take place in the tooth-thickness to diameter relationship. The tooth proportions change in involute gears when they are cut on diameters other than standard. Tapered gears are in reality a series of gears that have been enlarged (cut larger than standard) and reduced (cut smaller than standard) and stacked together. When they are produced on standard equipment with conventional tools, the tooth-thickness to diameter relationship must be considered or a faulty tooth bearing will result.

COST OF ZERO BACKLASH GEARS

Unfortunately, there are no short cuts to the accuracy with which gears must be built to operate metal-to-metal. The same accuracy must be applied to boring housings and selection of anti-friction bearings when they are specified. In gears, accuracy starts with the blanks. The finished gear can be no better than its blank. This is a point that cannot be overstressed. If a blank is inaccurate, no amount of painstaking workmanship can produce an accurate gear. Fortunately, current production methods lend themselves to a degree of accuracy that was undreamed of a decade or two ago. Gear shaving and gear grinding methods have been developed that economically produce gears of high accuracy. Lapping techniques and equipment for lapping hardened gears have been improved greatly in the past few years. It is not uncommon to lap gears that have been ground after hardening.

Since most applications that require gears of zero backlash do not have cost as a major consideration, techniques that would be prohibitive in highly competitive articles can be and usually are used. Among applications using zero backlash gears are machine tools, measuring instruments and fire control equipment. Selective assembly, variable centers, special selection of anti-friction bearings and occasionally hand lapping during assembly are all used when producing highly accurate gears that must operate metal-to-metal. New developments in gear production have greatly reduced costs. Secondary operations, such as shaving, grinding and lapping, usually pay for themselves as a result of increased production in the roughing operations. Gears are currently being ground from solid blanks with a high degree of accuracy and at speeds that were undreamed of a short while ago. In the past, an accurately bored gear housing was considered easier to produce than accurate gears. The pendulum is swinging the other way today.

MEASUREMENT OF BACKLASH

It has been pointed out that there are several conceptions of backlash, namely: 1. Backlash cut in a single gear considered purely as one tooth of a gear being thinner than the space of the mating gear. 2. Composite backlash which takes into account that gear teeth have a variety of different errors. Gears having composite errors affect the amount of clearance or back-

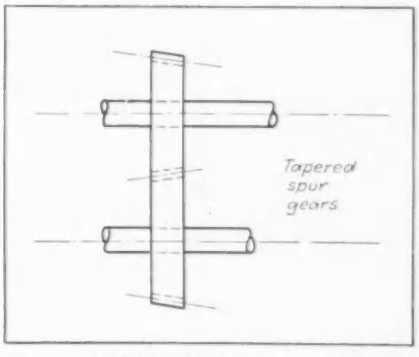


Fig. 7—Backlash in these spur gears can be regulated by axial displacement of one tapered gear relative to the other.

lash of other mating gears. The amount of backlash varies with the magnitude of the composite tooth error and the number of teeth in the arc of engagement. 3. Backlash in assembly. This takes into account all of the errors in the gears plus the errors in gear components, housing and shaft position.

The man on the gear cutting machine, in making a set-up, must be furnished with some means of obtaining size. This may be a gear tooth vernier, a set of gear measuring wires or some other type of tooth thickness gage. In using these measuring devices he learns one thing about the gear (depending on what he uses)—and that is all. However, the gear in operation rotates about an axis; when it does so in mesh with its mate, tooth thickness changes occur because of the errors previously mentioned. Therefore, the operator needs to know considerably more about the gear he is producing than just its tooth thickness. It is true, that the first requirement of any gear is correct size. It can be reasoned that if the set-up is correct with regard to proper selection of tooling, etc., the gear should be accurate. Fortunately, this is what happens in the majority of well planned and well-tooled jobs. There are some unpredictables that operators cannot evaluate, such as, springing of the work or cutter, non-uniformity of stock, etc. The only way to be sure that a gear has uniform backlash is to take it out of the machine and take a measurement for backlash made from its center. Tooth thickness must be established from its center of rotation, otherwise it is of no importance. The method of operation must be duplicated.

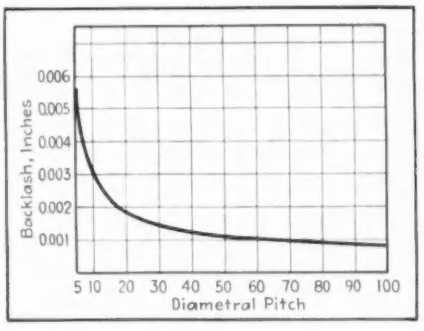


Fig. 8—Chart showing relationship between center distance and backlash.

The best way to check anything is to approach, as closely as possible, the manner in which it is used. When a gear is rotated in intimate contact with a master, both mounted on a variable center distance fixture, and their radial displacements are recorded, a composite check is obtained. Under these conditions, excluding the effect of backlash, the gears approach the manner in which they operate. Composite backlash can be measured as a center distance displacement. In gears of standard tooth proportions, the relationship between backlash and the change in center distance for each one-thousandth of normal backlash is: Center distance change equals two times the tangent of normal pressure angle. The curve of Fig. 8 gives the reduction in center distance per gear for each one-thousandth inch of backlash per gear for a pressure angle range of 14 to 30 degrees.

There are a number of different instruments on the market for determining the composite errors in gear teeth. These range from relatively simple instruments that are equipped with indicating devices for recording the radial displacements to the more elaborate type using charting devices. In the latter instrument, the total composite error appears as a chart similar to Fig. 2, on a strip of paper. All of these instruments use circular master gears with which the work gear is run. The present size range is fairly broad. Such instruments have been made for various types of gears such as, external spur and helical gears, internal spur and helical gears, worm gears and bevel gears.

Paradoxical as it may seem, the master gears currently available are not as accurate as a great many of the gears they are required to check. Industry is continually demanding more and more gears with a degree of precision that surpasses that of the master gears available. Because of this dearth of master gears of sufficient accuracy, many companies have had to use more analytical and slower means of determining gear accuracy. Gear checking procedures are being given energetic considerations by instrument builders and interesting developments are predicted for the near future.

There are many considerations connected with backlash in gears—design, application, manufacture, quality control and others. Some of them have been discussed in a very general way, in this article. It is hoped that attention has been directed to the several considerations that must be given to this problem and that each point be duly weighed in the order of its importance to the finished product.

Swiss Designs for Better Coal Utilization

AN "AERODYNAMIC" gas turbine, in which the working fluid is air circulated under pressure, is one of the outstanding Swiss wartime developments in the field of gas turbines and steam generators, according to a recent Office of Technical Services report prepared by OTS investigator Harold J. Rose. Swiss efforts have been aimed toward developing equipment for the more effective utilization of coal.

The economic situation in Switzerland during recent years has resulted in theoretical studies, engineering development work, and many commercial installations of ingenious methods for using energy more efficiently.

The "aerodynamic" turbine is so designed that combustion products do not pass through the turbine and almost any fuel can be used. The only restriction is that the fuel must not dirty the heating surfaces in the air heater. The Escher Wyss firm, developer of the turbine, claims that a thermal efficiency as high as 35 percent can be made possible after further development. Present efficiency figures range from 30 to 31.5 percent.

Commercial application of heat pumps is described in the report. These heat pumps are used industrially as well as for comfort heating and cooling of homes. In typical pumps, two-thirds of the useful heat comes from the water supply and one-third is supplied by the electric power used. With lower temperatures used in panel or radiation heating, it is said that as little as one-fifth of the total energy needed must come from the electric current used.

This report contains information on gas turbine development at the Brown, Boveri firm and Sulzer Brothers. The latter firm had a 7,000 shp oil-fired marine combustion turbine under construction, but little information was available during the investigator's visit.

Two new types of steam generators (boilers) that were introduced before the war have been further developed and are now accepted commercially. These steam generators are completely described in the report. Also included are discussions of research activities at the three firms visited.

Mimeographed copies of the 46-page report (PB-27435) cost $1.25. Orders should be addressed to: Office of Technical Services, Department of Commerce, Washington 25, D. C.

Patents and the Engineer

• PART TWO •

The final part of this special report discusses specific phases of the general problem of patent protection, described in Part I. After a patent is issued, new problems arise; the sale and rental of patent rights is an important one. Employer-employee relationships — the question of patent ownership — must be worked out, if new inventions are to be stimulated. The author describes conditions that are met in specific patents — mechanical, electrical, design and other types. For those interested in export, a discussion of foreign patents is included.

★

By

H. A. TOULMIN, JR

Toulmin & Toulmin

★

TOULMIN & TOULMIN
ATTORNEYS-AT-LAW

ASSIGNMENT

Whereas, ...

Letters Patent of the United States, ...

And Whereas, ...

dissirous of acquiring an interest in the same;

Now, therefore, in consideration of ... dollars, ... the receipt whereof is hereby acknowledged ... hereby assign, sell, and set over unto the said ... assigns and legal representatives, ... the right, title and interest in and to said invention for the United States and their territories and all foreign countries, and in and to said Letters Patent, divisions, reissues and extensions thereof in the United States and all foreign countries, and hereby request ... that said Letters Patent issue accordingly. For said consideration said ... agree ... to execute all papers that may be necessary to file applications in the United States and foreign countries for said invention and to assign the same to ... or any assignee acquiring title to said invention, and to execute any other papers that may be needed in connection with filing said applications and securing patents thereon.

In Testimony Whereof, ... execute this assignment this ... day of ... 194...

... [SEAL]

... [SEAL]

State of ... County of ..., ss.:

On this ... day of ... 194... before me, the subscriber, a Notary Public, in and for said county, personally came ... the assignor ... in the foregoing assignment, and acknowledged the signing thereof to be ... voluntary act and deed.

In testimony whereof I have hereunto subscribed my name and affixed my seal on the date last aforesaid.

[SEAL]

Notary Public, ... County, ...

My Commission Expires ...

License Agreement

This PATENT LICENSE AGREEMENT by and between NEW WRINKLE, INC., a corporation of the state of Delaware, with its principal office and place of business at Dayton, Ohio, hereinafter called the "Licensor", and THE ... COMPANY, a corporation of the state of ... with its principal office and place of business at ... hereinafter known as the "Licensee";

Witnesseth:

WHEREAS, the Licensor is the owner of the patents listed on the attached Exhibit "1"; AND WHEREAS, the Licensee is desirous of acquiring a license thereunder;

NOW THEREFORE, in consideration of One ($1) Dollar and other good and valuable considerations, the receipt of which is hereby acknowledged, the parties agree as follows:

1. Upon the terms and conditions herein set forth, Licensor hereby grants to the Licensee a non-exclusive, personal and indivisible license in and for the United States of America and Dominion of Canada, to make, use and sell the subject matter of the patents shown on the attached Exhibit "1", and of such other patents relating to the irregular finish of the patents shown on the trade as "Wrinkle Finish" [also known as "Crinkle", "Shirred", "Jing", "Morocco", and by other designations], as Licensor may now or hereafter during the existence of this license own or acquire, for all purposes and uses except, however, for use with fabric of woven cloth or of felt or paper as to which no license is granted hereby. Licensee shall also be entitled, upon the terms herein set forth, to a sublicense under any United States and Canadian "Wrinkle Finish" patents as to which Licensee now has or later acquires the right to grant sublicenses, such sublicenses also, however, to be subject to such usual and further terms and conditions upon which Licensee's right to grant sublicenses is acquired.

2. The Licensee hereby agrees to accept said license and to pay therefor a royalty of five [5] cents per gallon of wrinkle finish composition sold or used by it during the term of this agreement.

3. The Licensee agrees to pay said royalty between the first and twentieth day of each month for the gallons sold during the preceding month embodying the patented subject matter of this contract. This remittance shall be accompanied by a statement of the number of gallons sold, and books of account shall be kept open to inspection during reasonable business hours by the Licensor or its duly authorized representative, but the inspection of said books of account may, at the option of the Licensor, be by a certified public accountant, under instructions not to reveal anything about the confidential business or names of customers of the Licensee.

4. The Licensee shall mark all of its advertising, containers, etc., with suitable statutory patent notices as may be specified from time to time by the Licensor, and with the statement "licensed by New Wrinkle, Inc."

5. The term of this contract shall be ten [10] years, but may be extended under and upon the same terms and conditions as herein provided for further periods from time to time upon written notice from Licensee to Licensor, given at least two months before the date when the License would otherwise terminate. Licensee may, however, terminate this license and all its obligations hereunder at any time upon three months' written notice to Licensor. In case Licensee fails at any time to pay royalties, render statements or give access to its books and records as above provided, or otherwise violate or fail to observe the terms, conditions or covenants hereof, Licensor may terminate this license by written notice to Licensee to that effect provided Licensee has first given Licensee written notice of its violation or default and Licensee has failed for [30] days to remedy the same.

6. The Licensee hereby agrees not directly or indirectly to contest the validity of the patents set forth on Exhibit 1, prior to the termination of this License Agreement by lapse of time or otherwise.

7. The Licensee hereby reserves and shall have the right at any time to establish a Schedule of Minimum Prices, Discounts, and Selling Terms only in accordance with which Licensee, Licensor, and all other Licensees shall thereafter sell or otherwise dispose of products covered by patents included herein, and thereafter to modify.

An assignment records the sale of all or part of a patent right; a license covers rental of the right to make, use or sell the patented product. A license agreement is much more complex than an assignment, but both follow established patterns.

Sale and Rental of Patent Rights

Assignments and Licenses

The patent assignment is an outright or contingent sale of all or a part interest in a patent or patent application. Its form follows a rigid pattern: A statement of the subject matter to be assigned, the name of the assignor and assignee, the price paid, identification of the property, and the extent to which the interest is sold. The contingency, if not fulfilled, can cause reassignment of the interest.

Any part of a patent right can be rented; this is called patent licensing. This can be done either on an exclusive or non-exclusive basis, by agreement.

In drafting a license, a document much more complex than an assignment is used. It involves separate commercial provisions to cover every possible contingency. Its nearest equivalent is a real estate lease.

Before starting to write a patent license, or rental agreement, the parties should agree on fundamental points. The essential points in a patent license are:

1. A statement of the names and addresses of the parties and whether they are a corporation, an individual, or a partnership.
2. The purpose of the license.
3. The consideration for the agreement.
4. What patents or patent applications are licensed; whether the license is exclusive or non-exclusive, personal or indivisible, assignable or non-assignable.
5. Term of the license.
6. Royalties paid—on what basis and when.
7. Method of accounting and inspection of accounting books.
8. Marking of the licensed articles with patent numbers and manufacturing serial numbers.
9. Responsibility of protecting the patents licensed.
10. Responsibility of defending the patent against patent infringement suits.
11. Notifications by the licensor to the licensee of additional patents and patent applications or inventions.
12. Conditions of terms of the license in case of default by either party.
13. Place to which notices can be sent that will be binding upon the parties.
14. Provisions for renewal of the license.
15. Provisions as to price control of the licensed subject matter by the licensor.

The Law

An assignment of a patent or a patent application is a sale of property. The owner of such property can assign: The complete patent for the whole United States; the complete patent for a specified part of the United States; or part of the patent for the whole or a specified part of the United States.

An assignment is the sale of all rights under the patent, while a license is the rental of a right to operate under the patent for a royalty, based on the extent to which an invention is made, used, or sold. Both an assignment and a license give the transferee immunity from suit for infringement under the patent in question. The practical difference between an assignment and a license is that the former gives the assignee the right to sue for infringement, and the latter gives the licensee immunity from suit for infringement only. Chief Justice Taft clarified license rights, holding that transfer of the separate right to exclude others from making, using, and vending, without giving the right to the transferee to himself make, use, and vend, prevents such a transferee from bringing suit by himself.

The sale of an expired patent, coupled with an assignment of the right to sue for infringements committed prior to its expiration, is valid. To constitute an assignment, the exclusive right to make, use and vend must be of the entire patent, and not a part thereof. A transfer of less than the entire right is only a license, no matter what the language used. The assignment of the legal title of an invention, application for a patent, or a patent, can be made at any time after the invention has been completed.

The capacity of an owner of the patent to assign it is determined by the law of the state where the assignment is made. There must be provided in the assignment the rights of transfer. One of a plurality of executors or administrators can transfer the title to a patent. An administrator or executor can assign such a patent, which is personal property, without permission of court. The same is true when a patent is issued direct to an executor or administrator, after the decease of the patentee. The only way a court can assign a patent is by a decree compelling the owner of the legal title to execute the written assignment.

An assignment need not be acknowledged before a notary, but it is helpful in proving the assignment. An assignment can be executed by an agent, if its principal properly authorizes the action, but such an assignment must be in the name of the principal. When an assignment is executed by an officer of a corporation he does so as the agent of the corporation.

Many state laws regulate the assignment of patents, and the giving of notice as to such assignments, as well as indication that the consideration is for a patent. Before an assignment is made such state laws should be checked.

Conditions in Assignments

Usually an assignment is an unconditional immediate transfer of the entire right, talent, and interest of the patent owner, but many assignments are conditional. For instance, they may require a payment of definite increments until the total sum has been paid; or payment by royalties instead of a fixed sum; or restriction of the extent to which the assignee can operate under the patent; or restriction on the assignee assigning his rights.

A patent may be assigned on the condition that the title will revert to the assignor under specified conditions. These could include covenants regarding future inventions, guaranteeing the validity of the patent, and requiring the assignor to sign papers to protect the title. These are enforceable.

Warranties

One who assigns his patent cannot afterwards challenge the title of the patentee to whom he assigned it. An assignor of a patent is prevented by law from denying that he has title to the patent, but he cannot later contest its validity. However, one who assigns a patent does not guarantee that it is valid, unless he specifically agrees to it.

An assignee of a patent cannot make claim later against his assignor, that the patent is invalid, unless there is fraud or a guarantee of validity. If there is a provision in the license contract by which the licensee agrees not to contest the validity of the patent, this provision may be invalid under certain conditions.

When a patent application is assigned, there is no warranty that a patent will be granted; there is no implied warranty of commercial utility.

Joint Owners of a Patent

Many interesting questions arise as the result of a patent being owned by joint patentees. Such ownership is in equal parts; each has a one-half undivided interest in the patent. Receiving the entire title of one of two joint patentees can be considered the same as receiving an undivided one-half interest from a sole patentee.

There is no accounting for profits or other income between co-owners of a patent. Recoveries from infringers are divided in proportion to their undivided interests, but this rule is not settled. However, it is wise for joint patentees to have an agreement settling their rights and accountings between them.

Contracts to Assign

This question arises because of a special relationship such as employer-employee. There are three usual conditions in this field: Employment to solve a particular problem, which results in the invention; general employment, with an invention resulting from requiring the employee to solve a specific problem; and general employment where the employee makes the invention outside of his line of duty, but on his employer's time and using his materials.

In the first situation the invention would belong to the employer. In the second, where the function of the employee's department was to invent, the court held that the fruits of his endeavor belonged to his employer. In the third, the invention belongs to the employee, with a shop right to the employer.

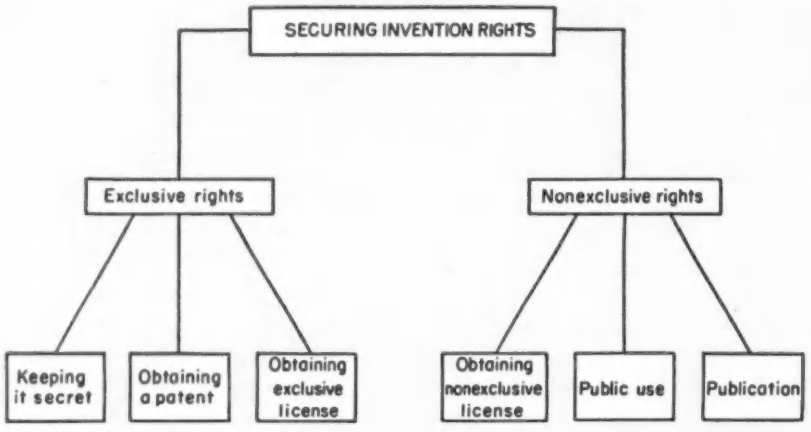
When the employee uses the time and materials of his employer in the course of his duties, the employer has an implied license or at least a "shop right." However, the mere fact that an inventor is hired to do research work does not render all of his inventions the property of the employer, unless covered by his contract.

An employee can make a contract to assign his inventions, but he cannot avoid that contract by making the inventions while off duty.

Recording Assignments

Federal laws and the rules of practice of the Patent Office provide that before a patent can be granted, issued, or reissued to a person other than the patentee, any assignments of it must first be recorded in the Patent Office. This means that the new owner will not receive the patent in his name as owner unless his assignment is on record before the Patent Office issues it.

To prevent fraud, federal statutes provide that any subsequent purchaser or mortgagee of a patent (for a valuable consideration) will be deemed the owner if it is recorded in the Patent Office within three months



Securing a patent is only the first—and perhaps the easiest—step in reaping the reward of an invention. Inventors should consider carefully which is the most expedient method of getting the patented product before the public.

from the date of the transaction. If it is not recorded, a subsequent innocent purchaser or mortgagee will have the prior right.

However, an unrecorded assignment made between assignor and assignee is good against infringers. Records of contracts agreeing to assign licenses can be recorded, but these do not constitute constructive notice of the existence of a license.

Before any license or contract is entered into, the assignee should have his lawyer check the assignment records, and require a certificate or warranty from the assignor that he has the right to assign or license.

The Patent Office recognizes the assignees of the entire interest for the whole of the United States and assignees of an undivided part of the patent or application for the whole United States.

In interference proceedings between two applications, to see who is the first inventor, the assignee controls such a proceeding, and it neither cannot be terminated or avoided without his consent.

General Character of Licenses

Licenses have no statutory basis. They operate purely under contract law. A license is a form of rental of personal property.

A license is binding any time the contract is signed, whether the invention is made or not. Usually a license is not signed until after the invention covered by it has been reduced to practice, either constructively by filing an application, or actually by building and successfully testing the invention. Contracts agreeing to grant license to future inventions are valid, if subject matter and time are limited.

There are several ways for a license to be "implied". A license is implied by the federal statute providing that the United States government can use any invention if it makes reasonable compensation. A license is implied on articles constructed or acquired before the application for a patent or issuance of a patent.

If an article is made and sold with the consent of the patentee or his assignee, before the patent issues, there can be no claim against the purchaser after the patent issues.

When a person buys an article outright from a patent owner or his licensee, the law implies the right to use or sell to others to use, but does not give any right to reproduce the article. There is an implied right to repair an article so purchased, but not to reconstruct it. There is no implied requirement that the repair parts must be bought from the patentee. The purchase of an element of a patented combination does not necessarily grant a license to use the entire patented combination. For instance, the sale of a lamp base, with the express agreement that it did not constitute a license under lamp patents, has been upheld by the courts.

An implied right to make, use and sell may come from an implied license arising from an employer-employee relationship.

Payment of Royalties

Royalties or rentals are based either on the manufacture, use or sale of a patented article, or on a combination of unpatented and patented articles, according to convenience of accounting. They can be based on volume or value of production, number of articles produced, amount manufactured, amount sold, or any other commercial basis.

When a number of patents are concerned, a royalty can be divided according to the relative value of a plurality. Royalty agreements can specify maximum and minimum payments. The period during which the royalties are paid is usually the life of the patent, unless otherwise specified. Royalty agreements can be made for limited periods, before or after the patent is issued. However, such an agreement cannot be repudiated if the patent later proves to be invalid, unless there is a provision in the contract covering this point. A licensee may even be forced to pay royalties after the patent has expired, under certain conditions.

The field within which royalties must be paid is determined by the scope of the patent claims. One who represents to the public that subject matter outside of the scope of the claims is within the claims of the patent, cannot later avoid responsibility for paying royalties on that patent.

Licenses can be terminated either by expiration of the patents, the terms specified in the contract, the option to terminate for default of royalty payments described in the contract, or for failure of paying the specified consideration. It is usual to provide in detail the grounds for termination. The license can be terminated by law, resulting from widespread infringement which the patentee has not stopped or cannot stop.

Licenses can also be terminated because of refusal of the licensor to supply the articles licensed, unreasonable delay in supplying them, false representations as to the character of the patented article, or its validity. After a license has been terminated the parties are free to act as if the contract had not existed. Thus, the former licensor can sue the licensee for patent infringement.

Cross-Licensing

There exists a popular misconception that cross-licensing is illegal. According to a court decision: "An interchange of patent rights and a division of royalties according to the value attributed by the parties to their respective patent claims is frequently necessary if technical advancement is not to be blocked by threatened litigation."

However, an agreement for cross-licensing and division of royalties when used to effect a monopoly or to agree upon and fix prices, violates the Sherman Anti-Trust Act. Thus, a patentee or patent owner can fix prices

as he pleases, but he cannot agree with his licensee on prices or effect price control by cross-licensing.

Advantages of cross-licensing are felt by four groups:

1. The patentee. A patent can be extremely valuable when combined with other patents, yet commercially of little value by itself. Also, there can be an interdependency of values, sometimes leading to a "deadlock". Thus, the patentee who puts his patent in a "pool" receives the benefit of other patents.

2. The manufacturer receives the benefit of multiple research and is enabled to adopt the most efficient and economical operation and devices without restriction from all patented ideas in the pool. Also, he can devote his energy to improvement and sale of his product without fear of litigation.

3. Industry is benefitted by standardization, increased efficiency and improved quality.

4. All these benefits are passed on to the consumer in the form of a better product at a lower price.

Trade Groups

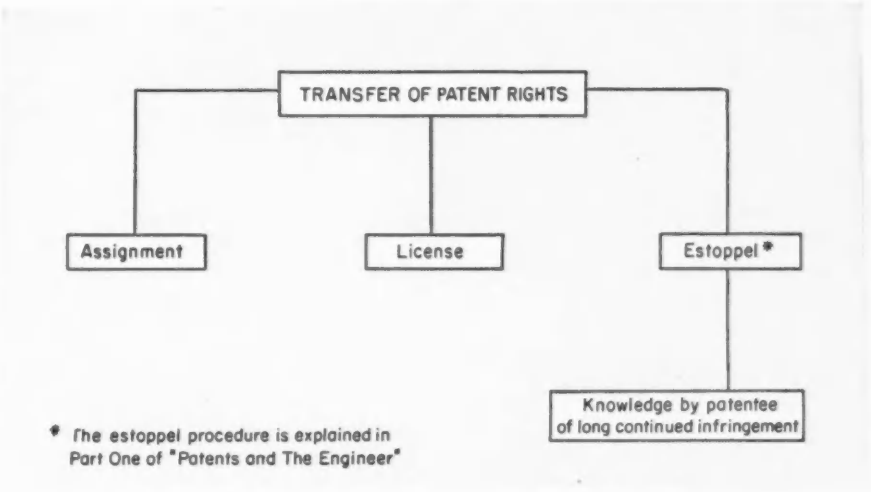
Various trade groups have adopted cross-licensing arrangements:

The basic patent issued to the Wright Brothers was broad enough to cover the warping of the airplane surfaces, or the use of rigid plane surfaces, and the movement of portions of these surfaces known as ailerons. Curtiss later developed the improvement of the aileron. The courts held that this improvement came within the basic Wright patent and Curtiss could not use the aileron. However, the Wright Brothers did not develop the aileron and would not have been able to use it because of the specific patent owned by Curtiss. Thus the public was the loser.

The Manufacturers' Aircraft Association acts as a cross-licensing agency. Any airplane manufacturer can join and have the use of all patents cross-licensed. The Wright and Curtiss patents were classified as Class "A" or basic patents. These were the only patents classified as basic patents. Patents classified as Class "B" are subject to royalties set by an arbitration board. Those in Class "C", improvement patents, require no compensation. Each member pays one-fourth of one per cent of the selling price to cover administrative expense.

The Government has a non-exclusive license to manufacture under the patents cross-licensed and it pays royalties only on Class "B" patents.

Cross-licensing agreements were adopted by the automotive industry when it was in the development stage.


TRANSFER OF PATENT RIGHTS
Assignment
License
Estoppel *
Knowledge by patentee of long continued infringement
* The estoppel procedure is explained in Part One of "Patents and The Engineer"

Responsibility of protecting the licensed patents should be defined in the license agreement. An assignment carries with it the right to sue for infringement; "automatic" protection in a license is negative—immunity *against* being sued..

A trade association of the automobile industry was formed in 1915. The pool included 547 patents in 1915 and 1687 in 1930; 1058 were still alive in 1935.

Since 1915 there has not been a single lawsuit between automobile companies. In a sense the automobile has been patented 175,000 times, yet relative technological peace prevails.

International Patent Pools

Territorial allocation and suppression of transocean traffic cannot be justified as ancillary to the grant of a license under a patent. The courts have ruled that: "Agreements creating a world-wide patent pool of all present and future patents of the parties, covering an entire industry, and embracing a division of the world into exclusive territories within which each of the parties is to confine its business activities, with respect to patent protected commodities, as well as unpatented, for the purpose and with the effect of suppressing imports into and exports from the United States, are unlawful under the Sherman Act; they constitute an unreasonable restraint of trade."

Who Owns a Patent?

THE COMPLICATED ASPECTS of patent ownership (see the accompanying chart) usually arise from employer-employee relationships.

The fundamental questions to be considered are:

1. Is the inventor employed to invent?

2. Does the employee have a contract to assign his inventions?

3. Is inventor an executive of the corpartion claiming the invention?

4. What is the position of the employee, without a contract to assign inventions in "line of manufacture", who does all the work on the invention on his own time and at his own expense?

5. What is the situation when the employee has a contract to assign his invention, but invention is outside the company's line of manufacture?

6. What is the situation of an executive with no contract to assign inventions, and the invention is outside of the company's line of manufacture?

Some of the fundamental kinds of ownership that arise in this connection are:

(a) Outright ownership by employer.

(b) Non-exclusive license to employer.

(c) "Shop right" to employer. This is the right of a company to continue to manufacture, use and sale of an invention in the particular shop in which the employee was located when he made the invention. Such a right is personal to that particular shop and disappears when the shop is sold.

(d) No ownership by employer.

(e) Exclusive ownership by employer.

One of the critical questions to be considered is whether the inventor was doing the work on the company's time or on his own time, and whether

OWNERSHIP OF PATENTS

		Idea Developed On		Experiment On		Reduction to Practice At		Test		Manufact	
		Company Time	Own Time	Company Time	Own Time	Company Expense	Own Expense	On Company Time	At Own Expense	On Company Time and Machinery	A E
EMPLOYEE	Employed to invent	A	A	A	A	A	A	A	A	A	
	No contract to assign	C	D	C	D	C	D	C	D	C	
EMPLOYEE Contract to Assign	All inventions	A	A	A	A	A	A	A	A	A	
	Inventions in line of manufacture	A	A	A	A	A	A	A	A	A	
	Inventions, but invention is outside company line of manufacture	B or C	D	B or C	D	B or C	D	B or C	D	B or C	
EXECUTIVE No contract to assign inventions	Invention is in line of manufacture	A or B	B or C	A or B	B or C	A or B	B or C	A or B	B or C	A or B	B
	Invention is not in line of manufacture	B or C	D	B or C	D	B or C	D	B or C	D	B or C	

A—Outright ownership by Employer.
B—Nonexclusive license to Employer.
C—Shop right to Employer.
D—No ownership by Employer.

he did the experimental work and the final building of the completed apparatus at his own expense or at the company's expense in the company's plant. In Heywood-Wakefield Company v. Small, 87 F. (2d) 716, Small was employed as a draftsman and later was promoted to the position of checker for the employer company which manufactured car seats for trolley cars and railroad coaches. The terms of his employment contained no reference to inventions.

". . . The plaintiff knew that the car seat base then manufactured by the defendant was unsatisfactory. The plaintiff's invention, however, was suggested to him by the mechanism of an electric toaster at his home. He worked on his idea at his home out of working hours and finally envolved what he confidently believed to be a satisfactory reversible car seat base. He made a blueprint and a cardboard model of his invention which he brought in and showed to Mr. Eickel, the head man in the checking department. . . .The next morning the plaintiff brought in what is termed a cigar box model, which the plaintiff had made at his home from thin board.

"Defendent's engineer advised him to put it in as a suggestion, to which the plaintiff replied that he did not consider it a suggestion and that he was not going to put it in until he knew what he was going to get for it.

"When, however, the officials of the defendant company had satisfied themselves that his invention was practical and solved their problem, they made every effort to secure an assignment of his patent, and, failing in that, sought to claim an absolute 'shop right'."

The Court found that ". . . . The record does not sustain the defendant's contention that it was entitled to a 'shop right,' as a matter of law. . . . It follows that the defendant was not entitled to an assignment of the patent."

Another important question is whether the invention is within or outside the "line of the company's manufacture". This question often arises because the company wants to go into new lines, although it had not been manufacturing that particular "subject matter" at the time the invention was made by its employee.

Generally, the law favors the inventor. The theory is that the corporation is at fault if it is not diligent in having proper contracts with its employees. The opposite rule applies when the employee is an executive. The courts say that the executive is in a position of trust and doubts should be resolved against him, because he is in a position superior to that of the corporation.

> **"We consider that the product of the employee's brains, while he is on the company's time and making use of the company's plant, belongs to the company to the extent indicated. But (if the company decides not to have the article patented) the employee-inventor is free to market his invention anywhere else . . . even to our competitors."**
>
> **—Executive of the Postal Telegraph Company**

It is generally presumed that if an executive makes an invention, even though he has no contract to assign inventions, and invention is within the line of the company's production it belongs to the company. It is assumed that the executive got his ideas from the company employees and from the company business.

It is wise to take some timely precautions with respect to the ownership of inventions. No company should employ anyone without a written contract stating what happens to inventions that employees make. This contract should limit time and subject matter, and it should clearly define the rights of both employer and employee.

If "outsiders" are employed—such as research laboratories, development organizations, special model makers or machine shops for making particular equipment—the purchase contract for this service should contain suitable provisions settling ownership of any resulting patents.

If there is no contract, complicated legal considerations, indicated in the chart, must be used. Here the rules of law come into play, usually require settlement as a result of court action, which is tedious, expensive and uncertain in its result. It is much easier to forestall these difficulties by providing for disposition of the right to inventions at the time employment is undertaken. This should be by contract.

How to Stimulate Invention by Employees

METHODS FOR REWARDING inventive effort fall into two distinct categories: (1) Rewarding members of the development, experimental or other department specifically charged with inventive functions; and (2) rewarding production or other workers, whose duties do not include development or invention.

How to Stimulate the Invention Department

Companies that maintain regular invention departments seldom directly reward men employed specifically to invent. But they usually find ways to stimulate them indirectly. Typical of most are the methods used by the National Cash Register Company, described by a member of the patent department: "Most of the important inventions are made by the several regular inventors who spend all of their time improving our registers. The problems upon which they work are usually assigned to them. . . . Each inventor is assisted by from two to five draftsmen of the best ability in our entire drafting force. . . . These assistants generally develop a very strong desire to become inventors independent of any supervision. This hope of promotion stimulates them to make suggestions independent of their regular assignments. We get some of our best inventors from this source."

The Eastman Kodak Company does not directly reward the members of its research laboratory or development department, but notably good work is encouraged by an appropriate salary increase. This automatically becomes an indirect bonus, since the company bases wage dividends and stock distribution on the employee's salary. The company considers it undesirable to provide a bonus for inventions in the research department, as it believes the practice would encourage abnormal secrecy and jealousy, and would diminish the teamwork that is essential for maximum results.

Departments vs Individual

Although most large firms make active use of the "individual" suggestion system, many have abandoned it in favor of an organized invention plan. The International Harvester Company, for instance, discontinued the suggestion system because it felt that shop workers were seldom in a position to know what improvements were needed. In that industry the development of new inventions usually comes about through the needs of the market. The suggestions to meet these needs come from men who are intimately acquainted with the new conditions—salesmen, general executives or the engineering department itself.

The Standard Oil Company utilizes both department and individual inventive effort. The company has contracts with the employees of its development department which bind them to turn over to the company all inventions relative to the company's business. Employees of other departments are not required to sign such contracts; those employees are urged to send in suggestions to a "coin your ideas" contest. Awards for the best suggestions are made by a committee on which the development department is represented.

Although the development or inventing department should be represented on the committee that awards prizes, the entire decision should not be left to such a department.

When a suggestion is turned down as impracticable, many concerns make it a point to explain the reason to the inventor, in a personal interview. In this way, many inventions that at first seemed useless have been found to be valuable. These talks also help to guide the employee's efforts along more practical lines, enabling him to make valuable suggestions.

An iron works in Pennsylvania has an interesting idea for stimulating employee inventions. Whenever one of its employees invents anything of value, it automatically secures a license from the inventor but takes out the patent in the name of the employee. It then permits him to dispose of the invention to others, and puts its money and patent department back of him. Of course, his concern gets its license free, but the fact that it loyally protects its employees has had excellent results.

An automobile company has a somewhat similar plan. Even though the invention of an employee is not and may never be of immediate value, it takes out the patent through its own patent department at its own expense in return for a license. The inventor may dispose of the remainder of his rights as he sees fit. His effort is noted on his record of efficiency, and is often reflected in a special bonus or increase of salary or authority.

SUGGESTION BLANK

In order that we may know exactly to what your suggestion applies, please state all information possible such as the name of the part or article, the number of the machine or work place, the process or method to which your suggestion refers and the building and floor number.

Remember that all suggestions that are adopted will be paid for in cash.

Keep your acknowledgments and refer to your suggestions by number. If you have several suggestions, use a separate sheet for each one.

On the reverse side of the sheet you will find a summary of the kind of suggestions we particularly appreciate and like to receive.

Date.....

I respectfully submit the following suggestion:

Rec'd_____
Ack'd_____
Accpt'd by Com._____
Ret'd by Com._____
Suggestor Not'fd._____

SUBJECT: Suggestion No.....

Suggestion No.....

Please sign name in full also give your Payroll Number.

Name ..... Dept. .....

Factory ..... Payroll No. .....

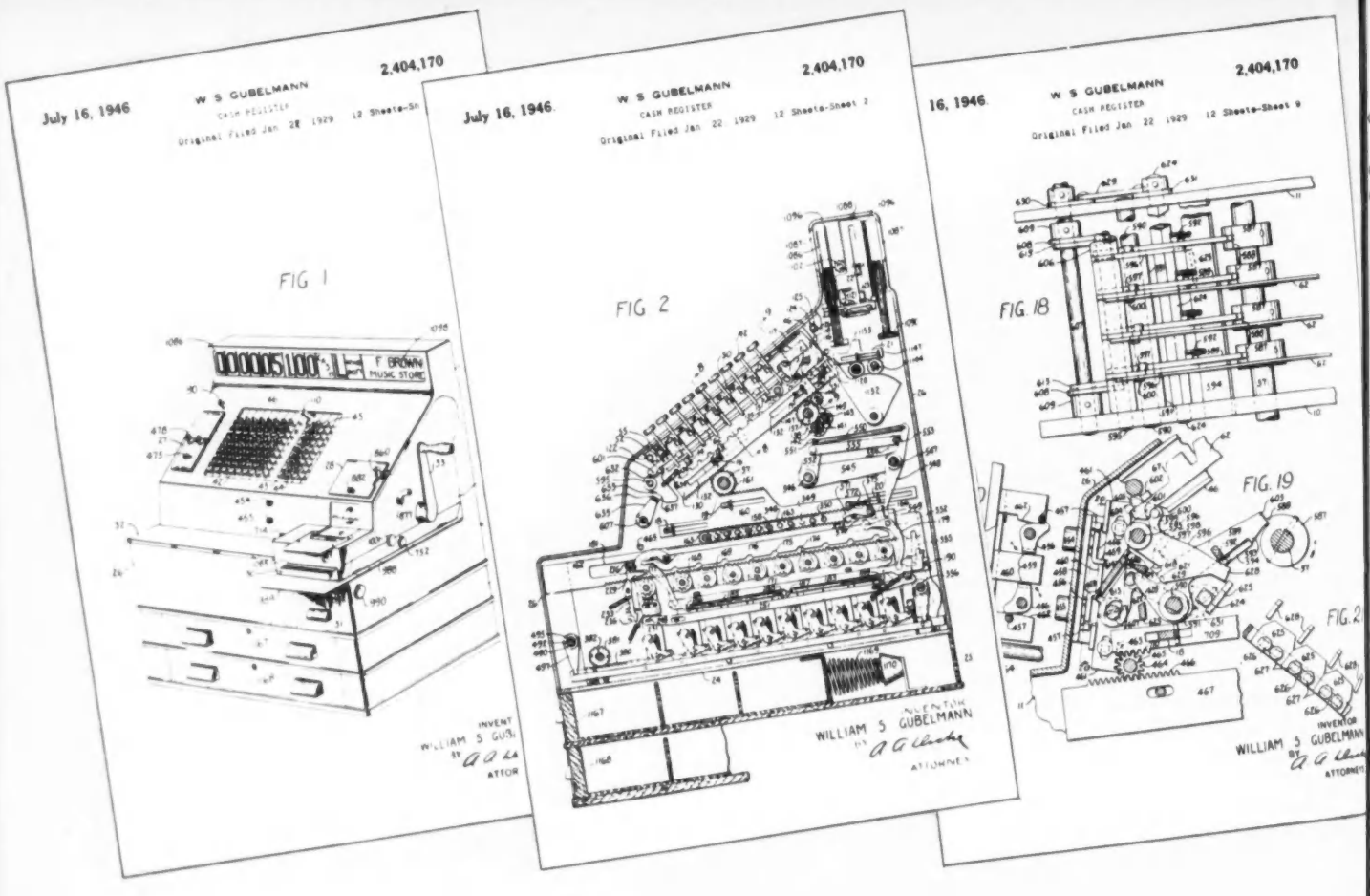
Easily available suggestion forms are a proven method of stimulating inventive ideas in employees who are not members of the inventing department.

Awards and Contests

There are two ways of handling suggestions: A contest in which those submitting the most valuable suggestions receive prizes; and paying for all valuable suggestions. The second is more successful.

Several methods of paying for suggestions have been tried by the Eastman Kodak Company. It has finally adopted the practice of awarding suggestions monthly, whatever they are worth, provided there exist suggestions worth awards. They have not restricted the amount to any set sum.

In most concerns the foremen are barred from receiving rewards for their suggestions. In Eastman Kodak Company, foremen are given a money award for suggestions which do not directly concern their department. For suggestions which do concern their department, they are given credit on their record cards which are reviewed periodically by the manager. The National Cash Register Company bars from contests all foremen, job foremen, section and department heads.



Complex products such as calculating machines are usually patented by breaking them down into "subcombinations." A subcombination is a combination of parts, forming a structure that accomplishes a specific function. Subcombinations can be patented separately; each functional subcombination, as well as the entire product, should be adequately described and claimed.

Special Types of Patents

Calculating Machines

Modern business machines such as tabulators, cash registers, adding machines, mathematical calculators, and complex navigation instruments are typical of the complex products that must be patented.

Calculating machine patents, often appearing impossible to prepare, can in reality be described, illustrated and claimed in a simple manner. To do this, a careful study of the subcombinations comprising the machine is made. The functions of the machine are studied, determining which subcombinations perform these functions and secure specific results.

The drawings should show the complete machine from different angles, and on different sections. After these assembly drawings have completely illustrated a machine, a skillful draftsman should illustrate the subcombinations in separate views, that they can be separately understood, described and claimed; and he should make diagrammatic views showing mechanically, electrically, pneumatically or hydraulically how the machine operates. He should do this, also, for the subcombinations and associate the simplified diagrammatic views, preferably in isometric perspective, with each subcombination that is claimed.

The object of this type of description is to make it possible for a United States Court, presided over by a non-technical judge, to understand readily how the machine operates, even though it is a complex machine when considered as a whole.

A recording type of taxicab meter, for instance, has from three to five thousand parts within a box approximately fourteen inches long, and six inches square. It takes many sheets of drawings and many more sheets of description and claims to illustrate correctly for the Patent Office, the courts, and the public, the contents of such a small container. But, it is done understandably by breaking down the intricate mechanism into subcombinations.

When drafting claims on such complex machines, this procedure is followed:

1. The machine is claimed *in toto*, as to its functions in terms of certain mechanisms that perform the functions. A typical claim reads as follows:

"In combination, means to feed a recording strip, means to print on such strip, means to actuate and calculate indicia registrations ultimately to be printed on such strip and means of ejecting and severing such strip from the machine."

2. Method of performance of the machine is claimed broadly:

"In a method of calculating and printing the results of calculations, the step (a) of initiating by pre-determined setting of the machine the presentation of calculating factors; the step (b) of actuating the machine to take from said calculating factors the end calculated result; and step (c)

of printing the calculated result."

3. There are many subcombination claims. Following is a typical claim of this type:

"In a subcombination in a machine for registering taxicab fares comprising a printing mechanism having plurality of printing wheels; means for feeding a strip of paper relative to the printing wheels, means for inking indicia appearing on the face of said printing wheels, and means of alternately inking said indicia with the inking means, and pressing the paper against the inked indicia on said wheels."

Such machines can embody a combination of electrical mechanisms, electric circuits, electronic mechanisms and circuits, hydraulic or pneumatic actuators, and various mechanical movements. It is possible to claim in combination any or all of such means of producing results.

In such mechanisms as the International Business Machines tabulator, which is a combined mechanical and electrical machine, certain of the patents could cover the combination of electrical and mechanical functions, while other patents are devoted specifically to one or the other. Thus, the secret of protecting a complex machine is to break it down by function and mechanism into subcombinations.

The courts have developed a number of special rules applicable to such machines. For instance, in a heel seat lasting machine, which forms and wipes the leather of the upper of a shoe over the bottom of a heel, before applying the heel, and tacks the upper in position prior to the placing of the heel on the shoe, the Supreme Court of the United States has held that it is correct practice to state the broad features of an old machine and claim in combination with that old combination the specifically new features that have been added to the combination as an improvement.

On this type of claim, the Court said:

". . . . claims refer to 'a lasting mechanism of the class described having, in combination. . . .' . . . .Other claims read: 'In a machine of the class described, the combination. . . .' Such preliminary statement is commonly and properly used to specify the type of machine in which the claimed subsidiary combination of elements works on improvements over the prior art. In describing the novel combinations embodied in the claims, it was necessary to make reference to certain portions of the machine in connection with which the new combinations were to operate and with which they were to dovetail, but, in mentioning these other mechanical parts, the claim does not purport to embody them as elements of the claimed combination. To construe such a claim for a combination of new elements intended to be embodied in some well recognized mechanical aggregation, such as a sewing machine or a washing machine, as a claim covering all the mechanical details, or all the well known parts of the machine, would be to nullify every patent for an improvement in a type of machine long in use and would invalidate thousands of patents for improvements in standard machines. . . ."

Subcombination Claims

Typical subcombination claims have been passed by courts, with varying results.

Claims should not merely recite aggregations of non-cooperating parts; true combination should be shown between the selective mechanisms, making the claims patentable.

To be allowable, a subcombination must include sufficient structure to accomplish the function stated. The method of bringing the subcombination into cooperative relation with other parts usually indicates how the subcombination effects a useful result. The subcombination need not be operative alone, because "utility is justly ascribed to things which have their use in cooperating with other things to perform a useful work." When the subcombination can be separated from the entire combination, it can be separately patented. A court decision stated that:

"In chemical cases it has sometimes been held that disclosure of given number of elements cooperating for fixed purpose will not support claims to lesser number of same elements designed for accomplishing same or different purpose, but in mechanical case general rule is that one is entitled to claim subcombinations of structure disclosed whether they have independent utility or not and whether or not original claims are drawn to such subcombinations."

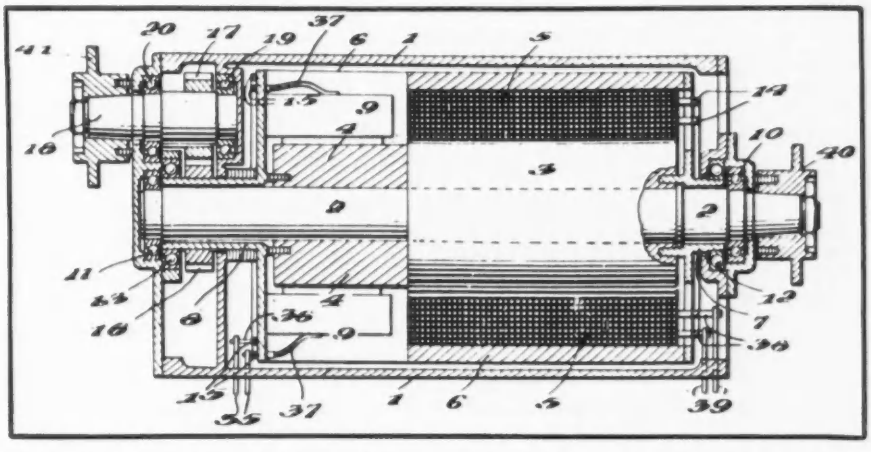
In part I of this report (June PRODUCT ENGINEERING) an aggregation was differentiated from a combination, as being a mere collection of parts. However, there are parts intended for "alternate" use, which are not mere aggregative parts. The keys of a typewriter, the keys and stops of an organ and variable speed transmissions are examples.

Elements for accumulating a series of numbers, totalizing, and printing both the individual items and the totals are incorporated in a single claim. If all the elements of the claim contribute to the production of a single result, the claim is not usually considered aggregative.

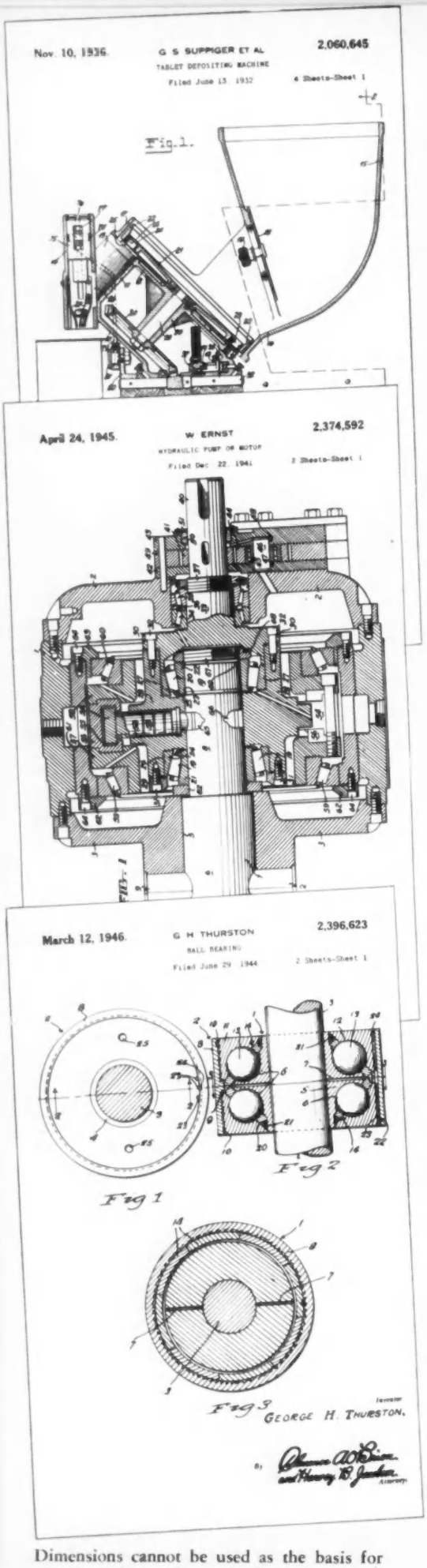
Mechanical-Electrical Combinations

A claim using the word "combination" and describing overload and underload circuit breakers with attendant electro-responsive means and a rheostat, means just that the circuit-breakers are applied to the same rheostat; there is no cooperation of the circuit-breakers, and the claim is invalid.

Claims to a photoelectric tube, and means for forming on a photosensitive unit of the tube an optical image, represent a true combination rather than an aggregation because there is



True combinations must be more than a mere collection of parts. An example of a valid mechanical-electrical combination is this electric motor and support, which has separate bearings for rotation of the armature shaft and field winding housing in either direction, by means of two gears. One gear is fixed and concentric with the housing; the other is keyed on a shaft that is journalled in the support. The gears engage continuously, and power is taken directly from the armature shaft.


Nov. 10, 1936. G. S. SUPPIGER ET AL. 2,060,645
TABLET DEPOSITING MACHINE
Filed June 13, 1932 6 Sheets-Sheet 1
Fig. 1.
April 24, 1945. W. ERNST 2,374,592
HYDRAULIC PUMP OR MOTOR
Filed Dec. 22, 1941 2 Sheets-Sheet 1
March 12, 1946. G. H. THURSTON 2,396,623
BALL BEARING
Filed June 29, 1944 2 Sheets-Sheet 1
Fig 1
Fig 2
Fig 3
GEORGE H. THURSTON,
Inventor
By Adams & Weaver and Harry B. Jordan
Attorneys

Dimensions cannot be used as the basis for patents, unless a change in dimension causes a qualitative change in performance of the product. Patented products based on "critical" dimensions vary from ball bearings to all types of weighing and metering devices.

cooperation between the optical system and the photosensitive element of the tube. A furnace stoker operation controlled by an independently operable thermostat constitutes a combination and is patentable.

An applicant for a patent can claim a regulating system itself or in combination with an electrical circuit, where there is mutual action and the system has no separate utility. Claims to a multi-operation washing machine and controls were not held aggregative, because the separate motor for driving the switch was merely a specific detail in the general control mechanism. "Merely" adding means for conducting electric current to the motor to the means for forcing lubricant to the bearings was not regarded as aggregative. Coupling of a motor that will run any kind of a machine to a machine that will run with any kind of a motor is not invention.

When determining infringement of complex mechanisms, the alleged infringing mechanism is rarely precisely like that of the patent. A court commented on this question as follows:

"Where an invention is one of a primary character, and the mechanical functions performed by the machine are, as a whole, entirely new, all subsequent machines which employ substantially the same means to accomplish the same result are infringements, although the subsequent machine may contain improvements in the separate mechanisms which go to make up the machine."

One of the problems in complex machine patents is to determine which prior patents and publications are applicable and not applicable. If you find an earlier patent in the cash register art or in the calculating machine art, would it "anticipate" a somewhat similar mechanism for a wholly different purpose in the automatic telephone art?

In International Standard Electrical Corporation v. Ooms, a patent application for a calculating device, composed of parts used in a telephone exchange system, was held to be new because it was not clear to persons skilled in the calculating machine art although it was clear to persons skilled in the automatic telephone art. What was known in the calculating machine art would not necessarily be known in the automatic telephone art. Commissioner Ooms (no longer in office) was reversed.

The Supreme Court has held that control of a part cannot be used to enlarge an already acquired control of the whole. A patent on the combination embodied in the complete machine, without the allowance of the subcombination claims would not prevent the free use of the subcombination.

The Supreme Court has also ruled that it is not improper to have a patent on a broad combination and also a patent on the subcombinations. Also, it is not improper for the owner of the patent to manufacture merely under the subcombination patent.

The fact that either the main patent or the subcombination patent or both is not used by the patentee or the owner of the patent does not affect the validity of the patents.

Close Limit Industries: Dimension Patents

Dimensions are generally regarded as not patentable or being subject to monopoly. It is generally true that a mere change in dimension does not usually cause anything other than the natural result. However, there are many exceptions to this rule.

When the diameter of a carbon filament in an electric light differed from an earlier carbon burner by only 1/64 in. or less, the patent was sustained.

In the weighing scale industry where accuracy is essential to success, a patentee made his integrating drum lighter than any previous worker in the art, changing failure into success. This, the court said, was something more than a matter of magnitude, because unreliable automatic computing scales were no scales at all, and a reliable automatic scale was a new mechanism worthy of protection. In that patent, thickness of the aluminum frame and the paper cylinder were not specified, but the patentee said that the skeleton frame should be reduced to the minimum thickness that would support the integrating cylinder; he further specified that the cylinder be of the thinnest paper that could then or thereafter be found in the market, stiff enough to retain its shape when attached to the frame. The court said that these were clear and definite instructions as to how to practice the invention, and the patent was sustained.

Another patentee provided a wider spacing of teeth on one edge of a hacksaw blade than on the opposite edge. This improvement produced a result that was outstanding and so unobvious to one skilled in the art that the court said it was invention.

One of the most interesting of all "magnitude" cases was that of American Ball Bearing Company v. Finch, which can be best expressed in the language of the court:

"What Baker did was to take the

common ball bearing hub, which he found in use in connection with the ordinary steering knuckle, and to move his spoke line or traction line from the center of the hub or its inner end, so that his spokes were mounted directly over his inner ball bearing. Incidentally, and as perhaps the natural step in connection with such mounting of the spokes, he made the inner balls larger than those at the outer end of the hub. In this way he reached a compromise between the old and common form, having excessive length in the short lever arm, and theoretically perfect, but practically undesirable, Faure form. He materially reduced the practicable length of this short arm. He minimized the disadvantages of the old form and the steering difficulties inherent therein, and he approximated the theoretical advantages of the Faure form, while avoiding the construction difficulties which had discouraged its use. We are convinced that this was invention. There is no way to demonstrate the rightfulness of such conviction. . . ."

In the case of Northern Equipment Company v. McDonough Automatic Regulator Company, there was an increase in the degree of inclination of a mechanism accompanied by an appropriate mechanical adjustment to get the desired result. But this, the court said, was only an indication, and not a cause of invention, for the reason that the invention lay in the discovery of a theory of operation which was new. The mere slight change in the degree of inclination was merely the physical execution of the fundamental discovery which should be protected even though the means of carrying it out was only a very slight change of dimensions.

This case illustrates a curious principle in patent law. A mechanical thing may be simple, but if the invention concept underlying it is fundamental, then it will be given broad protection as the physical embodiment of carrying out the invention.

The rule to observe in dimension patents was determined by the court in Bullock Electric Manufacturing Company v. Westinghouse Electric & Mfg. Company: "When the novelty of an invention consists in the dimensions or the material of the new thing devised, the patentee must specify the particular dimensions or the particular material his invention contemplates."

There is no difficulty in patenting an invention that is defined in terms of dimension or proportions, provided the definition is specific, accurate and essential to success.

Dispensing and Vending Machines

The effort to protect profitable business in materials that are dispensed by patented machines forms a large chapter on the history of patent litigation in the United States. This litigation has given rise to a new and different set of rules.

Any attempt to combine, in a single patent, coverage on the machine and the material that is dispensed by the machine or passes through it is doomed to failure. The attempt to profit from a patent on a machine which dispenses material, not from manufacturing, leasing and selling the machine, but from the control of the material dispensed by the machine, is likewise doomed to failure. This is true whether the material is covered by a patent or not.

If it is desired to control the product of a factory such as paper, salt tablets, dry ice or any other article of manufacture, the only way it can be done is by independent patents, and to use the patent laws in their normal way for such protection.

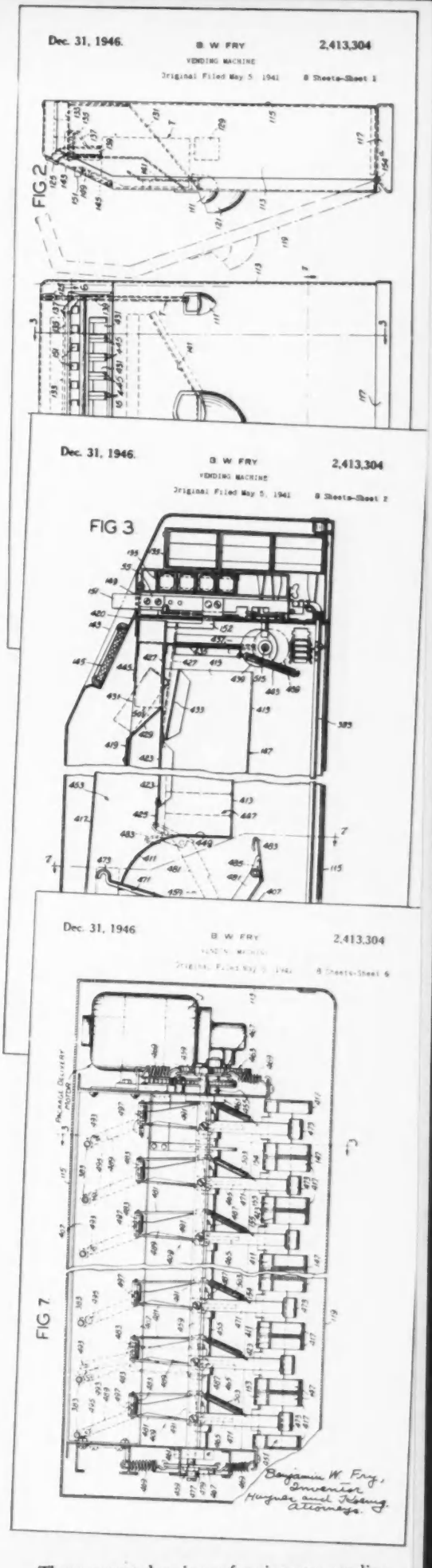
An owner of a patent cannot exact as a condition of the license that unpatented material used in connection with the invention shall be purchased only from the owner of the patent. Any provision that restricts free use of the machine under the terms of sale of the license will result in the temporary suspension of the patent rights.

However, the government cannot cancel patents, force their sale or appropriate them in an action for violation of the anti-trust laws, nor may any court in a private litigation take such drastic remedies. The courts can only exact penalties and conditions for the further use of patents, until their wrongful use is ended.

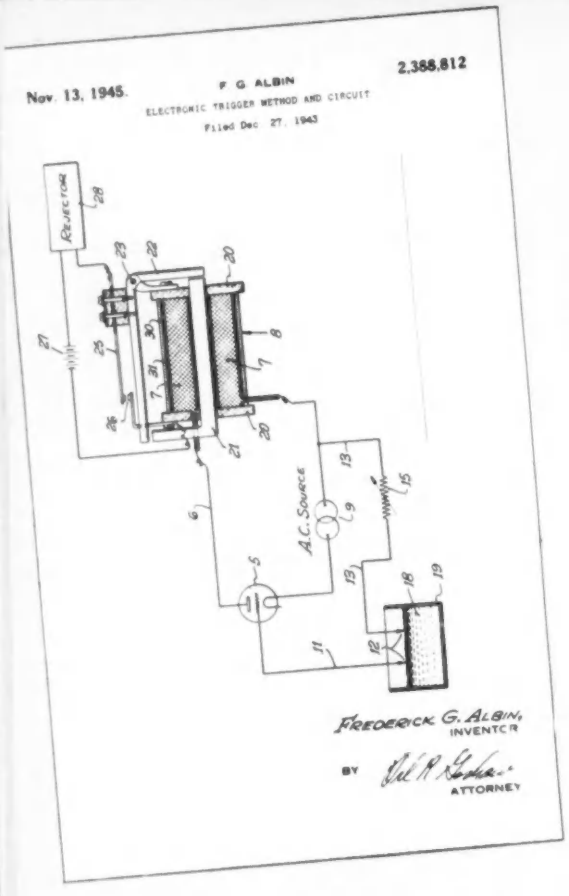
Electric and Electronic Patents

In 1943, the Supreme Court had before it the question whether Marconi's wireless discovery was legally an invention. The problem of the Supreme Court was to judge, forty years after the date of making the invention, whether Marconi's action was that of an electrical mechanic, or of a genius working beyond the mere skill of his art. The particular advance considered by the Supreme Court was the use of two high frequency circuits in the transmitter and two in the receiver. All four circuits were so adjusted as to be resonant to the same frequency or multiples of it.

Marconi's objective was to increase the efficiency of transmission and re-



Three patent drawings of a cigarette vending machine: Front and side elevation showing the partially removed front panel; vertical section taken on lines 3-3 of the top and bottom drawings; and horizontal section taken on lines 7-7 of the upper two drawings.



Typical electrical "method" patent: Obtaining maximum sensitivity of a trigger circuit for relay actuation, by rectifying an alternating current and reducing normal reactance in the relay circuit.

ception of signals by having the electrical impulses in the antennae circuit of the transmitter vibrate longer with the application to the transmitter of a given amount of electrical energy, and thus to increase the selectivity and the sensitivity of the receiver. Was the bringing of the four circuits into electrical resonance with one another, which brought about an extraordinary advance in transmission, invention?

The court found that Marconi had invented nothing over the earlier Stone patent, making the tuning of his antennae circuit adjustable. It found that he had not made an invention over Lodge's patent which showed the use of a variable inductance for the same purpose. Merely making a known element of a known combination adjustable by means of adjustment known to the art when no new or unexpected result is obtained is not invention.

Thus, the great success of Marconi, who created the art, did not save him from "anticipation" by prior patentees, who had never achieved his success.

Another interesting electrical case, dealing with a patent for improving cigarette lighters on the dashboard of an automobile, brought forth a decision that the use of a thermostat to break a circuit in a wireless cigar lighter is analogous to the use of such a device in electrical heaters, toasters, and irons. There is no invention in the adaptation of such a thermostat in a lighter on the dashboards of automobiles.

In General Electric Company v. Jewell Incandescent Lamp Company, the Supreme Court invalidated a patent on a frosted glass electric lamp bulb which used curves instead of sharp angles, to strengthen resistance against breakage. In another case the court invalidated a patent for a filament for an electrical incandescent lamp composed of tungsten, and made up of a number of large grains of such size and contour to prevent sagging and off-setting during normal useful life for such a lamp. The reason for invalidating the patent was lack of a sufficiently definite disclosure to enable workers in the art to accomplish the result that the patent claimed.

This is a very important point in electrical inventions. One who undertakes to get the monopoly of a patent in this field must lean over backwards to make a complete, candid and workable disclosure.

Scientific Discoveries

A principle, law of nature, or property of matter cannot be patented.

An artificial force is a natural force, so transformed in character by human power as to possess new capabilities of action. This transformation is considered a true inventive act. According to a court decision:

"A principle, considered as a natural physical force, is not the product of inventive skill. It is the common property of all mankind. It exists in nature independently of human effort, and can neither be diminished nor increased by human power. Man can discover and employ it, but his employment of it in the modes or through the instrumentalities by which it is applied in nature is a mere imitation of what every man is able to perceive and reproduce as well as he. All endeavors to confine it to himself are at once futile and unjust. It exists for all men, as well after his discovery as before. The laws necessarily recognize and protect this right, and do not permit any man to exclusively use the conditions which are the gifts of nature, simply because he was the first one to discover its value. Not until some new instrument or method is contrived for its direction toward ends which it cannot naturally accomplish does his creative genius manifest itself."

Mechanical Movement Patents

If a mechanical movement is patentable, it constitutes a "new and useful art," apart from the form of the mechanism.

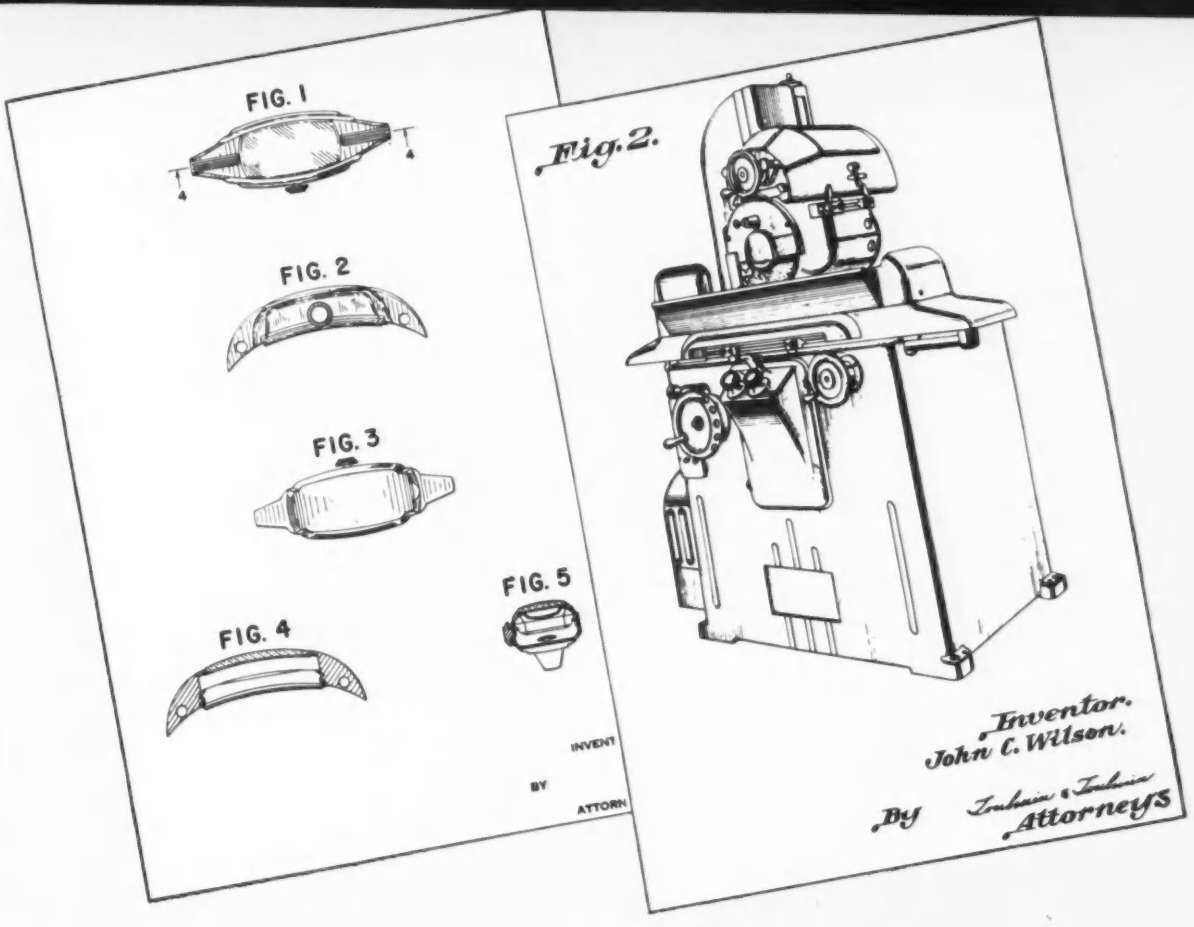
A claim for a mechanical movement is a patent not restricted to any particular kind of machine, although for proper illustration, it may be shown and described in connection with a specific machine.

A patent for a mechanical movement is for the combination and arrangement of mechanical parts intended for the translation or transformation of motion. If such a combination includes a subcombination, it is also patentable.

In a suit for infringement of a patent on machinery such as printing presses, it was contended that the characteristic feature of the patent was the use of the wrist pin on the main pinion and slots on the rack frame to accomplish the reversal of movement on the rack frame, while the pinion was wholly disengaged from the rack. However, the court held that there was no justification for the emphasis put upon the disengagement of the pinion from the racks and that the invention consisted in the combination of the racks, pinion, wrist pin and slots for the purpose of producing a uniform reciprocal movement of the rack frame.

In an infringement suit involving an automobile transmission mechanism, distinction was made between "overrunning" and "overdriving": "As defined, an overrunning device is one by which the driven shaft is disconnected from the drive shaft when the speed of the driven exceeds that of the drive. The overdrive device drives the driven shaft faster than the drive shaft by means of connecting gears and does not permit overrunning. The overruning permits the car to run faster than the drive shaft; the overdrive compels the car to go faster." The plaintiff contended that the novel features were: (1) An overrunning device, (2) a lock for the same, and (3) a centrifugal governor which would automatically lock out the overruning at a predetermined speed and cause the driven and drive shafts to come into a positive connection.

The court found that the overrunning feature and its lockout were not novel. They had been manufactured and used prior to the patent. That left as a basis of his claim to invention the addition to the free wheeling plus the cut out of a governor which automatically brought the last speed in the transmission to a non-overrun-



Design patents cover the external appearance or form of a part or machine, and have no relationship to the structure or performance of the device. Even when the machine is covered by a mechanical patent, its appearance can be protected by a separate design patent.

ning positive connection between the two shafts. But the patentee had not disclosed any such action in his drawings and typewritten specification which he claimed he had disclosed to the defendant in confidence before his patent issued; he lost the suit.

Design Patents

A design patent covers the appearance of an article or machine. Even though a machine is protected by a mechanical patent, its appearance can be protected by a separate patent. Generally, it covers that part of a mechanism that is exposed to public view. In this type of patent, the drawings are all important. The claim in the design patent usually reads as follows: "The ornamental design for a . . . ., substantially as shown;" or if a description of the design is given: "The ornamental design for a . . . ., substantially as shown and described." The specification is also simple. The drawings, however, must be quite complete. In effect, such a claim means that the patentee monopolizes the general appearance and artistic qualities of the machine, as shown in the drawings.

The term of a design patent is 3½, 7 or 14 years, as the patentee elects. Usually, the application is for a 3½ year period, and if the patent proves valuable, the applicant is permitted to increase the period of protection, by paying a larger fee. For a three and a half year term the fee is 10 dollars; for a seven year term the fee is 15 dollars; and for a fourteen year term the fee is 30 dollars.

In the design patent case, Gorham Company v. White, the court said that Congress intended to authorize design patents to encourage the decorative arts; and that the purpose of design patents was not to protect utility, as much as appearance, which is peculiar to the article. The object of the law is to protect those appearance features which enhance saleability of the patented article.

The true test of infringement of a design patent is whether the average purchaser would be confused by the similarity in appearance of the patented design and the "infringing" design—whether he might believe that the two things are alike.

A design patent covers only an article that is created by the exercise of inventive faculties. For instance, merely making a candle square instead of round would not involve the exercise of inventive design.

In design patents, the adaptation of existing devices to a new purpose does not constitute invention.

No lesser degree of inventive skill is required in the production of designs than in other kinds of patented articles. In a mechanical patent there must be novelty and utility; in a design patent there must be originality and beauty. Mere mechanical skill is not sufficient. The adaptation of an old device or form to new purposes, however convenient, useful or beautiful, is not considered invention by the courts.

More is required of a design patent than being new and pleasing. The design must be the product of invention—the conception must demand exceptional talent beyond the skill of the ordinary designer. The mere fact that the design is popular with the public and causes large sales is not sufficient for it to be considered invention.

Just how much ornamentation over and above that of the prior art is to be regarded as essential cannot be stated definitely. In mechanical patents a combination of old elements is not invention unless there is a new coaction among the elements, produc-

ing a new result, not flowing from the individual characteristics of each of the elements. In a design combination, if coaction between the consolidated elements is to be regarded as necessary, it must flow from a new, unexpected, ornamental and pleasing appearance, brought about by combining the old elements.

As with mechanical patents, the questions of validity and infringement depend on the state of the art.

If the infringer has appropriated only what is within the skill of the art, the patent cannot be sustained, and in a design case infringement will probably not be found. Expert witnesses are of no value in such litigation. The comparison is made by the court between the drawing of the plaintiffs' design patent and the defendant's construction. The comparison is not between the plaintiff's commercial product and the defendant's commercial product. In determining infringement, functional features are excluded.

One of the most important questions in design patents is its reduction to practice. In mechanical, electrical, and some types of chemical patents, the filing of a patent application with drawings and description with claims can constitute a constructive reduction to practice, equal to actual building, testing and operating the invention. However, a design patent of a three-dimensional article must be embodied in some structure other than a mere drawing.

Foreign Patent Protection

RIGHTS TO AN INVENTION can be divided territorially. One group of persons can have the right to manufacture and sell in one state or group of states, while others may have similar rights in another part of the country.

United States patents cannot be avoided by manufacturing the invention outside of the United States and then shipping it into the United States. This has been frequently tried and always results in failure. Conversely, United States patents extend only to the borders of the United States, our territories and possessions, but not outside of our jurisdiction. Hence, anyone learning of an important development in the United States can go into a foreign country, if there are no foreign patents taken out in that country on the subject, and manufacture and sell anywhere outside of the United States, To prevent this, manufacturers in the United States secure patents in foreign countries.

As far as the United States is concerned, the inventor can be a foreigner as well as a citizen of the United States. The privileges of foreigners are further defined in the reciprocal treaties that we have with other countries.

Our laws provide that applications filed in the treaty country shall be effective in this country from the date it was filed in the foreign country, and shall carry the same protection as if it were filed here. In addition, however, the application must be filed in the United States before printed publication anywhere; or if published abroad, it must be filed within twelve months (six months for design patents) from the earliest date of any publication. Duration of the patent in this country is unaffected by subsequent expiration of a foreign patent for the same invention or by reason of non-payment of taxes or non-use.

Inventions of minor importance should not be protected abroad, unless they fit into a plan of overall protection which the manufacturer has already established.

Foreign patent protection should be limited to the more important inventions. Particularly important are all kinds of business machines, domestic appliances, progressive labor-saving devices and processes, machine tools, and machines that reduce cost of manufacture. Also of great interest for the export market are all types of optical and chemical products, which were largely supplied by Germany before the war.

Patent protection in England, Canada, Australia and other British dominions has the two-fold advantage of protecting exported goods and obtaining a market under preferential tariff conditions. For this reason, many American concerns have located manufacturing plants in these countries.

To meet competition in the world market, it is often advantageous to obtain a patent in the country where the product is being made, and from there shipped to foreign countries.

In establishing a foreign patent policy, these questions should be considered by the manufacturer:

1. Which are the primary markets of the world in which competitive manufacturing and competitive selling will take place?

2. Which foreign manufacturers own competitive patent rights in the United States, for which the manufacturer can trade his patent rights in the competitor's country?

3. Which manufacturers abroad can be licensed, to control their competition? should royalties be received? This would help control prices, and would lead to an exchange of ideas and technical information.

It is possible under foreign laws to combine certain American patent applications, which are separated in the United States Patent Office, thus greatly reducing the cost.

In many countries, particularly in Latin America, the one registering the trademark is sole owner, the registrant will have then the right to confiscate goods bearing the original trademark when it arrives in that country. This actually happened to a number of U. S. concerns who failed to register their foreign trademarks, in advance of shipping.

The fundamental lesson of all trademark experience abroad is that no single step is of greater value to a corporation than the protection of its trademark rights overseas. Trade marks should be identified through some well-known symbol, even though the American name is unpronounceable and means nothing to those purchasing the goods. The color may have a special religious or social significance which may either meet with approval or be violently prejudicial in certain countries.

Trademarks and patents go together. A product that is protected both by patents and trademarks is in a far stronger position than one protected by either patents or trademarks.

In European countries invention has been throttled by patent laws that require the inventor to manufacture under his patent or lose it; or the inventor must pay heavy annual taxes for the privilege of keeping his patent alive. This short-sighted policy has put so many barriers in the path of inventors and manufacturers that by contrast the United States is progressive, because its inventors are protected and rewarded for their initiative. A study of the number of patents taken out in the United States and in foreign countries shows that the number of these patents is approximately in direct proportion to the industrial success of the respective nations. This is a practical proof of the wisdom of our policy.

VITAL DATA FOR SECURING FOREIGN PATENTS**

Country	Term of Patent	Latest Time for Filing	Documents Required	Who May Apply	Novelty Examination	Opposition
entina*	5, 10 or 15 years from date of grant.	Before printed publication or public use anywhere. Printed foreign patent no bar to confirmation of patent if there has been no public use in Argentina.	For ordinary applications: Specification and claims in duplicate in Spanish; drawings in duplicate; legalized power; combined legalized power and assignment if assignee applies. For confirmation of patent: In addition a certified printed copy of foreign patent and a translation thereof by sworn translator.	Inventor or assignee.	Yes	Not possible.
tralia	16 years from date of filing or convention date, if filed under convention.	Before publication or public use in Australia. If filed under convention, within one year of date or first foreign application, interim publication or use is no bar to validity.	For ordinary applications: Specification, claims and drawings in duplicate; application form; power of attorney. For convention application: alternative application form; in addition, certified copy of U.S. basic application.	Inventor, assignee or communicant.	Yes	Possible for three months after advertisement of acceptance.
zil	15 years from date of grant.	Before printed publication or public use anywhere. If filed under convention within one year of date of first basic application, interim publication or use no bar to validity.	For ordinary applications: Specification and claims in duplicate in Portuguese; drawing in duplicate; legalized power; combined legalized power of assignment if assignee applies. For convention application: In addition certified file wrapper with the contents of basic application.	Inventor or assignee.	Yes	Possible for 60 days from publication.
ada	17 years from date of grant.	For ordinary applications before issue of patent on earlier filed foreign applications and within 2 years of printed publication anywhere and public use in Canada. When filed under convention, within 1 year of date of filing first basic foreign application.	For ordinary application: Specification in duplicate, claims in duplicate; drawings in triplicate; power of attorney; assignment in duplicate if patent is to issue in name of assignee. For convention application: in addition certificate of filing of basic U.S. application, or certified copy of basic foreign application.	In general inventor only; under certain conditions (Patent Act, Section 29, Sub-section 2) also assignee.	Yes	Not possible.
nce	20 years from date of filing.	Before publication or public use anywhere sufficient to enable the invention to be worked. If filed under convention within one year from filing date of basic foreign application, interim publication or use no bar to validity.	For ordinary and convention applications: Specification and resume in duplicate in French. Drawings in duplicate, power of attorney; assignment when filed in name of assignee. Certified copy of basic foreign application if filed under the convention.	Inventor or assignee.	No	Not possible.
eat Britain	16 years from date of filing of ordinary application. If filed under convention, 16 years from convention date. If application is filed with provisional specification, patent expires 16 years from date of filing of complete specification.	Before publication or public use in Great Britain. If filed under convention within one year from filing date of basic foreign patent, interim publication or use no bar to validity.	For ordinary application: Specification, claims and drawings in duplicate; application form; power of attorney. For convention applications: In addition, drawings in triplicate; certified copy of basic foreign application; assignment if assignee applies.	For ordinary applications: The inventor alone or jointly with assignee. For convention application: the inventor or his assignee. For communicant application: communicatee alone. Inventor.	Yes	Possible up to three months from advertisement of acceptance.
land	18 years from date of grant.	Before publication or public use anywhere sufficient to enable the invention to be worked. If filed under convention within one year from filing date of basic foreign patent, interim publication or use no bar to validity.	For ordinary application: Specification and claims in duplicate in Dutch; drawings in duplicate; power of attorney. For convention application: In addition, certified copy of basic foreign application; assignment of assignee applies.	Inventor or assignee.	Yes	Possible for 4 months from acceptance.
dia*	16 years from date of filing, or from date of basic application in Great Britain, Ceylon, Union of South Africa, Australia, New Zealand, Canada or Irish Free State if filed under inter-colonial arrangements.	Before publication or public use in India or within 12 months from date of filing application in Great Britain, Ceylon, Union of South Africa, Australia, New Zealand, Canada or Irish Free State.	For ordinary applications: Specification, claims and drawings in duplicate, power of attorney; application forms signed by applicant. If assignee applies, assignment of consent required. If filed under inter-colonial arrangements, certified copy of basic British or colonial patent or application required.	Inventor assignee or communicant.	Yes	Possible for 4 months from publication.
aly	15 years from date of filing.	Before publication anywhere. If filed under convention within one year of date of filing of first basic foreign patent, interim publication or use no bar to validity.	For ordinary applications: Specifications, claims and drawings in duplicate in Italian; legalized power. For convention application: In addition certified copy of basic foreign patent. Legalized assignment if assignee applies. Certified translation into Italian of certified copy in support of convention application.	Inventor or assignee.	Yes	
xico	20 years from date of filing or from convention date. (Patents limited to 15 years when not worked.	Before printed publication anywhere except when applicant first applies in Mexico and obtains patent within 12 months from date of use or publication. If filed under the international convention within 1 year of filing date of basic foreign patent, interim publication or use no bar to validity. Publication or public use within 6 months prior to convention date will not invalidate patent obtained under the convention. For countries giving similar rights to Mexicans, an issued patent is no bar for 6 months after issuance.	For ordinary application: Specification, claims and drawings in duplicate in Spanish; authorization, assignment when assignee applies. For convention application: In addition certified copy of basic foreign patent.	Inventor or assignee.	Yes	Not possible.
eden	17 years from date of filing.	Before printed publication anywhere or public use in Sweden. If filed under the convention within one year from filing date of first basic foreign patent, interim publication or use no bar to validity. First showing of invention on international exhibition no bar to valid application, provided application is filed within 6 months from said exhibition.	For ordinary and convention application: Specification, claims and drawings in triplicate in Swedish; power of attorney. Combined legalized assignment and power of attorney if assignee applies.	Inventor or assignee.	Yes	Possible for 2 months from acceptance.
itzerland	15 years from date of filing.	Before publication or use in Switzerland. If filed under the convention within one year from filing date of basic foreign patent, interim publication or use no bar to validity.	For ordinary application: Specification and claims in duplicate in French, German or Italian; drawings in duplicate; power of attorney. For convention application: In addition certified copy of basic foreign patent. Assignment if assignee applies.	Inventor or assignee.	Yes	Not possible.

*Not a member of International Convention. **Space limitations prevent inclusion of data on all countries; these can be obtained from the Editor of Product Engineering or the author.

PATENT CLASSES ARRANGED BY EXAMINING DIVISIONS

DIVISION 1

4. Baths, Closets, Sinks, and Spittoons
268. Closure Operators
256. Fences
99. Foods and Beverages, subclasses 234–450. (See Division 63 for other subclasses.)
59. Gates
55. Harrows and Diggers
47. Plant Husbandry
111. Planting
97. Plows
275. Scattering Unloaders
182. Sewerage

DIVISION 2

119. Animal Husbandry
6. Bee Culture
17. Butchering
31. Dairy
43. Fishing, Trapping, and Vermin Destroying
100. Presses
68. Textiles, Fluid Treating Apparatus, subclasses 241–277. (See Division 27 for other subclasses.)
131. Tobacco

DIVISION 3

252. Compositions, subclasses 2–8.05, 62, 67–79, 181.1–301.6, 372–408. (See Division 64 for other subclasses.)
22. Metal Founding
148. Metal Treatment
75. Metallurgy

DIVISION 4

193. Conveyors—Chutes, Skids, Guides, and Ways
302. Conveyors—Fluid Current
198. Conveyors—Power Driven
187. Elevators
37. Excavating
227. Fire Escapes
294. Handling—Hand and Hoistline Implements
228. Ladders
214. Material or Article Handling
262. Mining, Quarrying, and Ice Harvesting
243. Pneumatic Dispatch
304. Scaffolds
186. Store Service
212. Traversing Hoists

DIVISION 5

181. Acoustics
24. Buckles, Buttons, Clasps, Etc.
49. Glass
56. Harvesters
84. Music
274. Sound Recording and Reproducing
289. Tying Cords or Strands

DIVISION 6

260. Chemistry, Carbon Compounds, subclasses 1, 124–139, 349–397.7, 429–664, 684–708. The distribution of class 260 among the Examining Divisions is as follows:

Subclass	*Division*
1	6
96	50
97–123	15
124–139	6
140–208	43
209–235	15
236–297.5	59
298–326	15
327–348.6	63
349–397.7	6

DIVISION 6—Continued

Subclass	*Division*
398–428.5	63
429–664	6
665–683.6	31
684–708	6
709–773	38
774–813	15
814–822	38

DIVISION 7

88. Optics
95. Photography

DIVISION 8

5. Beds
155. Chairs and Seats
45. Furniture
65. Kitchen and Table Articles
312. Supports, Cabinet Structures
211. Supports, Racks

DIVISION 9

230. Gas Pumps and Fans
253. Motors—Fluid
170. Motors—Fluid Current
103. Pumps

DIVISION 10

Abolished Apr. 10, 1942
C. O. 3617

Classification of Patents

DETERMINING whether there is patent infringement and whether a patent is invalid depends on the state of the art and on "anticipation". This means that prior efforts in the same field, shown by prior public use and sale or prior publications and patents, must be discovered. A similar search must be made to determine if the patent is valid.

There are three kinds of patent searches: (1) A preliminary examination, or short search to determine novelty of an idea; (2) an exhaustive, formal search for all patents that a particular structure or process might infringe; and (3), a formal search to determine whether a patent is valid.

These searches require an investigation of domestic and foreign Patent Office records, usually including libraries of the Patent Office, Library of Congress, and public and private institutions. Because organization of knowledge in the United States is not highly developed, this is often a difficult task.

A customary practice is to search through the United States Patent Office records for similar patents. The Patent Office is classified in hundreds of classes and sub-classes, which are listed in the Manual of Classification, a sample sheet of which is shown on this page. A special classification division of the Patent Office constantly arrange and classify patents by subject matter in these various classes.

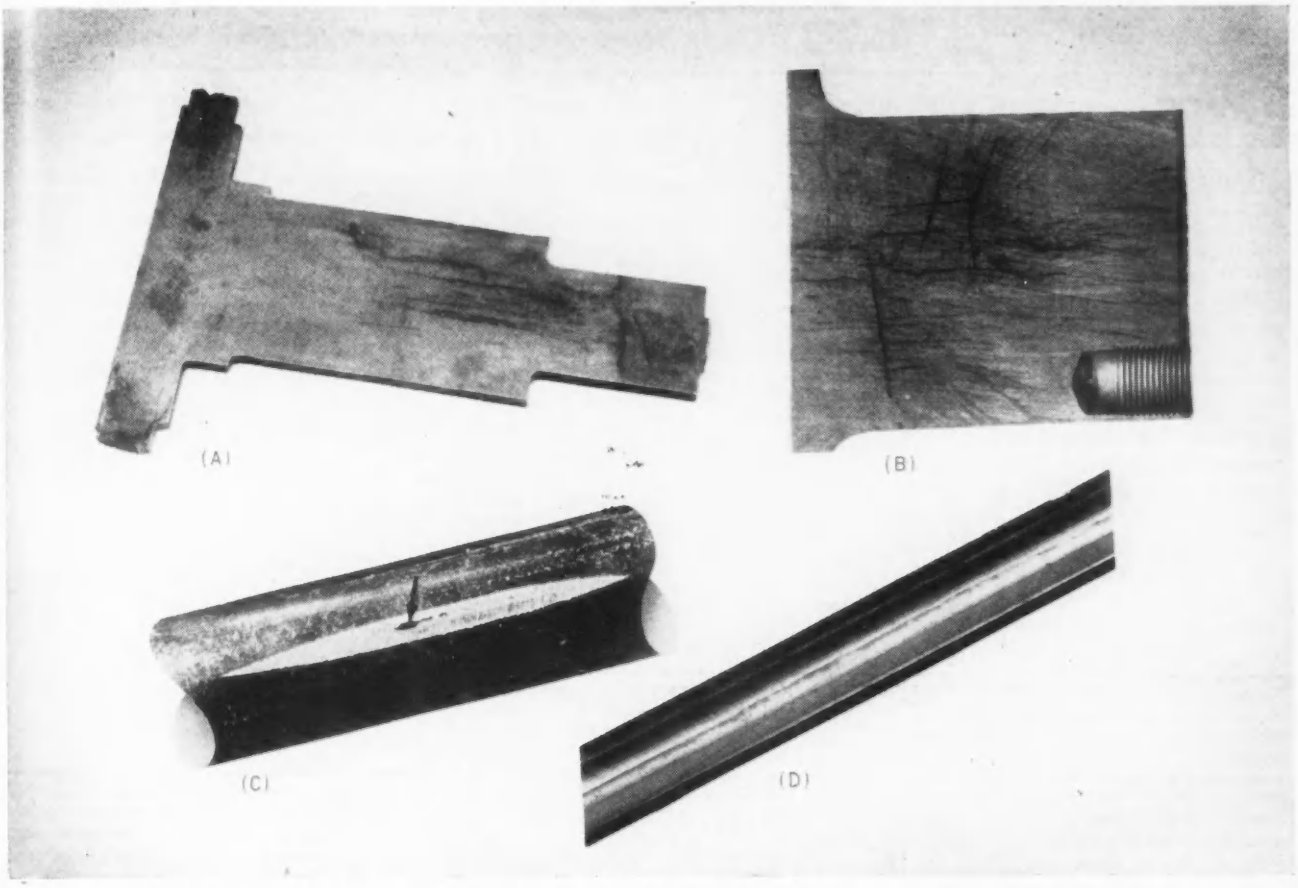
Preliminary examination search is a brief review of the most likely groups of patents in which anticipation of an idea can be found.

In a formal search, the first step is to review the classification manual. When examining the hundreds of bundles of patents under each classification, so many additional cross references will be found, that it is possible for a searcher to pass from group to group endlessly. To avoid this imagination is required to determine where similar mechanisms might be found. For instance, an air blower patent was found to be completely anticipated by a mechanism in an oil fired furnace used to control the oil supply.

This ability to visualize relationships is the basic qualification of a competent searcher. In addition to exhausting the possibilities of the Patent Office Classification Manual, the searcher will probably confer with the examiners in charge of the classes involved and seek permission to look at their personal working files, including their collection of foreign patents.

Searching foreign patents is difficult. The patents are not classified carefully in many countries. The classifications are different and often there are available only abstracts, not the complete patents. The difficulty of language creates another problem. However, many "anticipation" cases come from foreign patents, so that foreign patent searching is absolutely necessary.

THE AUTHOR: Harry Aubrey Toulmin, Jr. is known to Product Engineering readers as the author of many informative articles on patent practice and research. He brings to the patent field a viewpoint that is sympathetic to engineering problems, since he is the head of a commercial research laboratory. Making his headquarters in Dayton, Ohio, Mr. Toulmin has won both national and international importance in this field through his own practice and his books on various phases of patent law. . . . This two-part report just concluded—"Patents and the Engineer"—is based on Mr. Toulmin's forthcoming book, "Patent Handbook," to be published by D. Von Nostrand.



TYPICAL DEFECTS in metallic parts that were disclosed by non-destructive tests. After rejection on basis of supersonic reflection tests, sections of two forged steel axles showed the (A) longitudinal and traverse cracks and (B) shrinkage cracks. Parts rejected after electric current flow tests were sectioned and found to contain (C) inclusions and (D) seams.

Non-Destructive Test Methods

Seven basic methods for non-destructive testing of materials.

BENSON CARLIN
Product Engineer, Sperry Products, Inc.

WHEN CHOOSING A METHOD for testing a material, the development or design engineer must first evaluate certain key considerations. For instance, many times first cost and ease of operation of the testing method is of paramount importance. Therefore, the first step is to analyze the problem, perhaps by answering such questions as:

1. Can magnetic variations be measured in the material?
2. What is the surface, shape, and size of the part to be tested?
3. What type of flaw is involved?
4. Must the test be made after final assembly?
5. Which test method is the simplest to interpret and the most economical to use.

The answer to these questions inevitably limits the type of test to one or two of the methods discussed in the following and compared in the chart. Final selection depends upon the relative advantages of the testing method for the particular work involved.

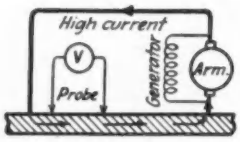
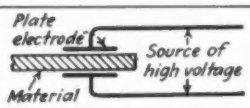
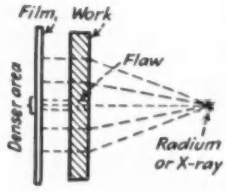
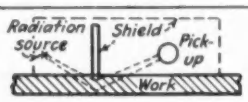
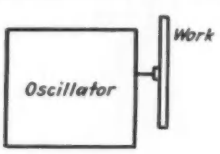
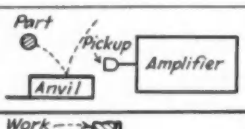
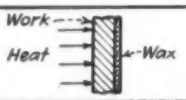
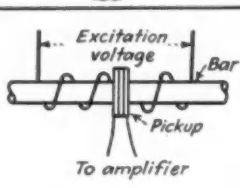
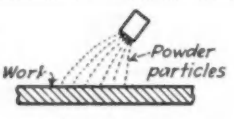
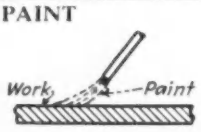
The number of different methods for testing materials has increased greatly during recent years. Each method has inherent characteristics that make it especially useful under certain conditions.

BASIC REQUIREMENTS

Basic requirements for simple, low-cost systems by means of which any or all discontinuities in a material can be located and classified include: (1) Location of defects without the indication of acceptable inhomogeneities; or, a method of differentiating acceptable and non-acceptable defects; (2) consistent, accurate, and rapid operation; (3) a minimum of skill required from the operator; (4) method and apparatus that is adaptable to automatic operation and when desirable to production requirements, and (5) method must be non-destructive, and not dangerous to personnel. Most of these requirements are vital to the user, and all to the designer of the test method and equipment.

There are many basic approaches to the problem of indicating when the internal structure of a material changes. It may, for example, be done by observing the difference between a characteristic of a normal sample and one of a particular part under examination. This is a comparative rather than an absolute standard. Usually other forms are preferred. Most non-destructive test systems are divided into two basic types: (1) Devices that measure the transmission of a particular type of radiation through a part; and (2) devices that measure the amount of radiation scattered or

Table I—Comparison of Characteristics of Non-Destructive Testi

Method and Use		Operation	Sensitivity
CURRENT FLOW: Location of flaws and measurement of wall thickness, especially where walls are corroded.		High current is passed through the pipe, or test object, and voltage drop across a portion of the current path indicates resistivity of that section. Probes must make good contact. D-c or a-c can be used.	Not determined to date.
BREAKDOWN: Location of small holes in non-conductive sheet material.		High voltage is applied across two flat electrodes and the part passed between them. Any hole or flaw lets current flow through it. Range of voltage applied can be adjusted to suit material.	Detects flaws of any size flashover voltage of the rial itself.
RADIUM (1) AND X-RAY (2) PENETRATION: (1) Testing of metals in the field such as, tanks or inclosed parts. (2) Testing welds, castings, forgings, plastics, assemblies.		(1) Rays from a capsule of radium penetrate the article under test and impinge upon a film. Density of film varies with the amount of transmission; where flaw occurs rays penetrate more easily and film is denser. Capsule can be temporarily or permanently fastened within a body. (2) Same as (1), except that X-ray tube produces rays. X-ray voltage required: Thin sheets aluminum, magnesium, plastics, 3 to 50 kv; aluminum or magnesium 4 to 6 in. thick, 30 to 150 kv. Steel with respective thickness of: 1½ in., 60 to 250 kv; 2 to 2½ in., 400 kv; 5 to 6 in., 1,000 kv; 8 to 12 in., 2,000 kv.	½ of 1 percent of metal ness; 2 percent easily obta
REFLECTION: Determining pipe and wall thickness, including corroded bodies.		Radiation from an X-ray or radium capsule is scattered and then reflected, or back scattered. Radiation increases directly with the wall thickness.	Extremely gross sensitivity
SUPERSONIC OR SONIC REFLECTIVE: For testing metallic or plastic objects of regular shape.		A pulse of energy is transmitted into the part under test, and reflected from its opposite face, or from an included flaw. The time of travel discloses the position of the reflecting object. Sender and receiver can be a single crystal or two separate crystals.	Practically unlimited; size of the material or the of the included particle only limiting factors.
TRANSMISSIVE: For testing thin strips of material of flat parallel shape.		Energy is transmitted through the material. If it penetrates it, the material is good; if the beam is interrupted, the material is bad.	Extremely sensitive. Same itations as reflective type cept also indicates changes in position.
RESONANCE: Measures the thickness of parts from a few thousandths to four inches.		Ultrasonic energy is varied over a frequency band that includes the resonant frequency of the part. At resonance, least energy is required from the driving oscillator. Thus the indicator can be calibrated in thickness, since there is one specific resonant frequency for each thickness of material. Variations include: (1) One or two crystals; (2) pulsed or continuous wave; (3) different types of indicators. Different ranges required for variety of thickness.	Limited only by scatteri the ultrasonics within the as in badly corroded sect
VIBRATION: Especially useful for small metallic parts, such as ball bearings.		The part is vibrated and the sonic or ultrasonic output is analyzed. Work may be hit or dropped. Sound can be analyzed in different manners.	Limited to flaws that are with respect to the total o
THERMAL Testing for bond or lamination.		Heat is applied or induced, and detected on the opposite side of the part.	Readability difficult.
MAGNETIC BAR: For testing ferrous and non-ferrous material.		Bar under test passes through a magnetic head and current is induced in the material. Current sets up a flux field that is constant as long as there is no change in cross section. Flaws are detected by coils scanning surface. Also material can be placed in a coil with a secondary winding about it, and distortion of the wave shape evaluated. Magnetization can be in different orientations. Meters or other indicators can be used.	Location of flaws is limited their position.
POWDERS: Examination of materials, especially ferromagnetic ones.		After surface is magnetized, powder is spread on it and the configuration examined for changes in pattern caused by discontinuties. Discloses strictly surface conditions or those a small distance below the surface. Can be dry or wet, such as oil paste; can be colored for contrast with part.	Good sensitivity on well ished surfaces only.
PHOSPHORESCENT PAINT Good only on surface. Used on such materials as stainless steel, aluminum, brass, bronze, carbides.		Surface is dipped or painted in highly phosphorescent material, then washed with paint remover. A second liquid draws out the phosphorescent material that remained in surface flaws, which is visible under black light.	Good within its limitations

Test ethods

General Considerations
hod is rapid, automatic, and cheap. Main dif-ty is spurious indications caused by electrical tacts. Contact potential is troublesome since the sured voltage usually is extremely low. There wide normal variations in a material's resis-y.
y size ellent for inspecting rapidly moving sheets. the s no indication of size of flaw. Accuracy is ted by voltage applied.
netal th re is some danger in using radium. Penetration y obtai off rapidly with the thickness of the part. Two ore exposures are necessary for stereo readings etermine the depth. Flaw must have thickness he direction of exposure. Size of the flaw located mited by the thickness of the material. Films are icult to read. Critical as to angle of penetration; inations are not indicated.
sitivity uracy limitation is about 5 percent. Method not perfected; depends upon development of tech-ue for measuring the scattered radiation.
ited; n other than location of the flaw, interpretation or the he trace is required. Other indications than those particle ired may appear. Usually indicator is a cathode s. tube. Apparatus is portable, economical and uires little maintenance.
. Same atisfactory with large size laminations or flaw. e type uracy is limited severely by spurious indications. tes m
catter uracy is about 2 percent of the thickness, and in the mited only by the accuracy of the indicator. l sectio hod widely used for checking thickness of com-ed parts such as propeller blades.
at are y small parts can be tested; only gross discon-otal ob ities revealed. Satisfactory for specialized test-, such as for screws or coins.
icult to heat evenly; gross indication only. thod is not perfected.
limited s must be extremely close to the surface. Effect external magnetic fields, including earth's, may troublesome.
n well ge surfaces easily tested; can be recorded by ing Scotch tape over the particles, which ad-e to it. Accuracy limited by distance of flaw n surface.
tation d for surface defects, such as cracks into which paint can settle.

reflected by discontinuities within the part. Besides these two basic types there are several other minor groupings, such as instruments that only indicate the characteristics of a material's surface, or those that only show a gross discontinuity of the part as a whole.

Common types of testing using transmission of energy include: (1) Electrical methods that measure the amount of current passing through a material, (2) the radium or x-ray methods that measure the amount of radiation passing through the material, (3) supersonic methods that measure the amount of vibrational energy passing through such a medium, (4) heat methods that measure the transmitted amount of heat and (5) magnetic methods that measure the passage of flux.

All these systems have the common characteristic of measuring the final amplitude of a form of radiation that passes through the material, and many techniques can be commonly ascribed to all systems.

Among the more common reflective types of testing are the ultrasonic types that measure the reflection of the pulse, and the gamma ray types which measure the amount of radiation scattered by discontinuities within the material. At present, the transmission types are the more common. But for the future, the reflective types will probably be increasingly used as a result of the application of advances in radar and other hf techniques developed during the war.

Among the surface types of test are those that use (1) fluorescent paints spread over the surface and (2) magnetic particles that trace out the magnetic field on the surface of the part.

The location of gross defects is usually accomplished by vibration of the part as a whole. It is strictly a qualitative measure.

Methods Compared

Electrical. The electrical tests that measure the amount of current flowing in an article are basically limited by the necessity for excellent contact. Often the amount of contact voltage or resistance makes it impossible to use this type of test. It is useful in locating gross flaws that are large enough to interrupt or constrict the current flowing in a part. Also it can measure the wall thickness of corroded tanks and other parts. The orientation of the flaws located must be across the direction of current flow since if they are parallel to it there will be no essential interruption. Instead of direct contact, certain electrical tests induce currents in the material. Indication of a flaw can be picked up by (1) passing a coil over the surface that detects leakage flux caused by discontinuities in the current path, or (2) using probes to measure the difference in voltage drop across the surface.

Generally, the direct electrical type of test is not satisfactory for gaging moving objects because the contact must be dragged over the surface of the object. Also when the parts under test are changed, conditions of contact must be exactly the same.

Radium and X-ray. These techniques are widely known and used for test purposes in industry. They are excellent for most applications where the flaw is a large percentage of the amount of penetration, or for testing small parts of an irregular shape and no thicker than about 12 in. Also they are useful to examine the orientation of parts within a shell; for example, to determine if all the parts in an electrical motor are included in the assembly. This type of test is not satisfactory on pieces of great thickness and the greatest drawback to its use is the expense and size of equipment necessary for its application. For example, one million volt machines require permanent installations of considerable size, and must be shielded by masses of concrete or other material.

The amount of penetration of the rays or of their scattering can be measured. When scattering is important, after the scattered energy is reflected it is picked up by an indicating counter or integrator. Such instruments differentiate poorly between a part, such as a wall, and a deposited corrosion on it, or a liquid lying against it. The length of time of exposure is relatively long for each reading since the unit measures a summation of scattered energy for a time interval. The longer such an interval is, the more accurate the reading.

An advantage of X-rays is that the film provides a permanent record. Ordinarily gamma ray techniques are used where portability is important.

X-ray and gamma ray techniques have made and are continuing to contribute to the field of non-destructive testing.

Ultrasonic. Ultrasonic testing has been widely used recently and is most effective in the testing of large masses of material that are relatively regular in shape and composition. (See Product Engineering, October 1947,

p. 113) The test surface of the material must be smooth. Reflective methods are superior to transmissive ones since (1) both the flaw and its location are indicated, and (2) there is less likelihood of false readings. Ultrasonic testing is fast since as the quartz crystal scans the test surface the reflected pulses appear on the oscilloscope screen. In through methods of ultrasonic testing, usually the object under test is immersed in a liquid bath and slowly moved between two crystal units. A meter indicates the amount of energy transmitted through the object.

Ultrasonic resonance testing methods are used to measure thickness of thin-skinned objects, such as aeroplane propellors. The object must be fairly regular and smooth. Ranges in thickness from a few thousandths up to a few inches can be rapidly tested. Resonance can also locate laminations or flaws as long as the overall distance between the lamination and the face of the crystal is within its range.

THERMAL. Thermal testing is inexpensive but little used because it lacks exactness. Not only concealed flaws, but many other factors affect the heat conductivity of the material. At present no available instrument is suitable for such test methods. But such tests are made with waxes and sources of heat to obtain qualitative data. Generally, it is difficult to apply the heat at controlled rate and the physical setup is critical. Methods of reading exact temperature gradations are lacking and it is sometimes difficult to determine the melting points of various materials.

MAGNETIC. Magnetic testing is widely used and extremely successful in two major fields. (1) Magnetic powders are used for detecting flaws on the surface and those lying directly beneath the surface. The method is simple and economical and can be applied to almost any metallic object. A fine powder is spread over the object and the configurations which it takes because of the magnetic flux noted. (2) Tubing or bar stock is passed through a magnetizing head and the field examined by search coils. In this application both the orientation of the flaw and its depth below the surface is critical. Magnetic methods of test require relatively simple equipment but there is a tendency of spurious indications to show.

FLUORESCENT. Fluorescent paints sometimes are used for surface testing, but generally, are not satisfactory in locating flaws below the surface. A paint is spread over the surface, allowed time to sink into cracks and then wiped off. A second substance may then be applied to draw the paint out of the cracks.

LIGHT. Thin materials can be tested by the amount of light transmitted through them. It is not necessary for the material to be translucent, although in some cases it may be. But thin sheets of materials that do not transmit light can be tested for pin holes by placing a strong source of light on one side of the material and a phototube or similar pick-up on the other side. Any light transmitted through the material indicates small pin holes and the material is rejected. Such methods of test are extremely limited to thin sheeting and to the location of holes that extend through the material.

EXPANDING FIELD

The non-destructive testing of materials is now a large and constantly expanding field. Many new methods and apparatus will undoubtedly be developed in the near future and applied further to it, and the engineer must therefore be constantly aware of such work so he can apply it to his own problems.

Transmission of Direct Current Studied in Germany

ECONOMICAL TRANSMISSION of high voltage direct current was studied by Germany during the recent war, and tests are described and evaluated in an Office of Technical Services report prepared by OTS investigator Robert I. Stockland. While none of the research projects was carried to a successful conclusion, valuable data was discovered that will aid future research. Technical data on real and reactive load conditions in d-c transmission and on load regulation and safety control for d-c transmission systems are especially detailed.

Possibility of power transmission by means of a constant voltage d-c transmission by means of a constant voltage d-c transmission system was first demonstrated in 1936 in the United States by the General Electric Co. In this demonstration, 5,250 kw were transmitted at 30 kv for 17 miles. The Swiss Brown Boveri company demonstrated the feasibility of such transmission in 1939 over a shorter distance but at a higher voltage.

The German Siemens installation was used for an experiment similar to this. A power company in 1940 transmitted direct current on existing lines for a distance of three miles at 90 to 110 kilovolts.

One of the largest projects attempted was sponsored by the German General Inspector for Water and Energy in 1941. It was planned to transmit 400 kv from the Elbe power station of the Electrowerke A. G. to a Berlin station, a distance of about 70 miles. Two 200 kv underground cables were to be used for transmission. The report describes the synchronization of existing direct current and alternating current lines. The alternating current was to be converted to a suitable voltage by single-phase transformers and rectified to 200 kv d-c by single anode mutators. Both halves of each plant in each station were to be connected in series so that 200 kv d-c positive would be produced by one half and 200 kv d-c negative by the other. The neutral was to be grounded. Preceding systems all used grid-controlled mercury arc rectifiers.

Another system which was to transmit 16 milliwatts at 80 kv for three miles used an air blast rectifier designed by Prof. Erwin Marx of Brunswick Institute of Technology. The system did not prove satisfactory because of difficulties with the rectifier. Sufficient dust accumulated inside the tube after about 24 hours to cause a short circuit between electrodes. Mechanical filters were installed to overcome this trouble but without success.

Theoretical designs were set up for grid controlled mercury arc rectifiers to operate at 100 kv and up to 250 amp. Available test information indicates that these designs are not trouble-free but will require modification.

A wide variety of main and auxiliary transmission equipment, such as transformers, condensers, cooling equipment and piping, and circuit breakers is described.

Mimeographed copies of the report (PB-81824; "High Voltage Direct Current Transmission"; 259 pages) costs $6.50. Orders for the report should be addressed to the Office of Technical Services, Department of Commerce, Washington 25, D. C., and should be accompanied by check or money order payable to the Treasurer of the United States.

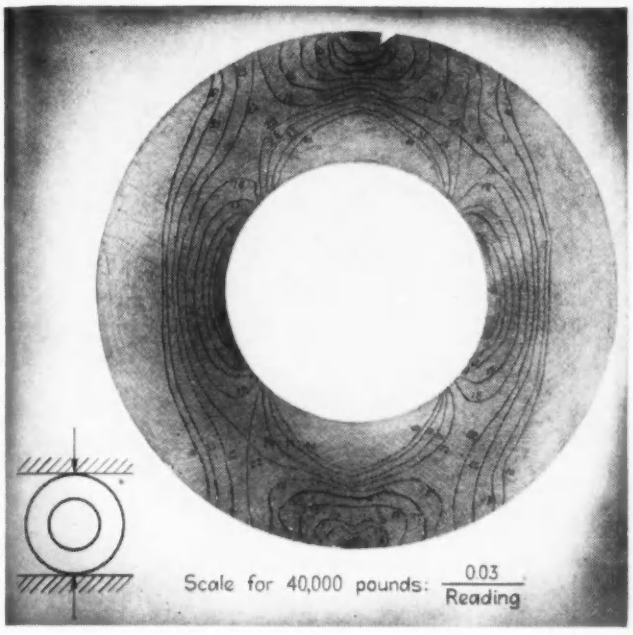


Fig. 5—Brittle coating pattern in a ring, giving isoentatic ϵ_2 and complete set of isostatics 1. Obtained by relaxation method.

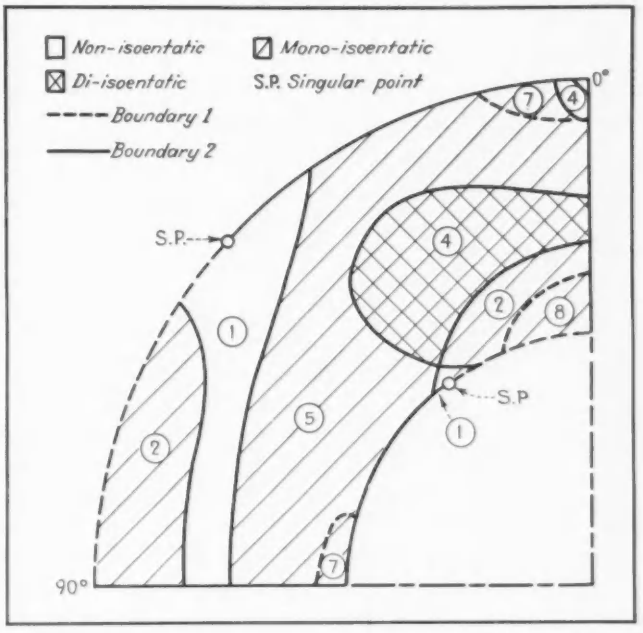


Fig. 6—Isoentatic zones for the ring are obtained by combining the patterns of direct loading, Fig. 2, and the Fig. 5 pattern.

What Kind of Information Does Brittle Coating Give?

PART II

Theoretical considerations developed in Part I are applied to distribution of stresses in a ring under diametral compression. Results are checked against values given by photoelastic studies.

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Armour Research Foundation
Illinois Institute of Technology

IN THE JUNE 1948 issue of PRODUCT ENGINEERING, Part I of this series developed methods and formulas for stress determination with brittle coating patterns. The reader should be familiar with the first part before continuing with Part II.

The distribution of stresses on a ring whose outside diameter is twice its inside diameter and loaded under concentrated compression has been treated quite extensively by, among others, S. Timoshenko and by M. Frocht. This allows rather easy checks on the results obtained using the brittle coating method.

Two important experimental difficulties should be kept in mind: (1) The resultant of the load applied to the specimen should coincide with the axis of the specimen but this cannot be checked before the final result of the tests. Some of the differences between the values obtained for the eight quadrants of the ring are therefore caused by eccentricity of the load. (2) The load is not applied to the specimen on a geometrical dimensionless straight line, but through a plane tangent to the ring. On the contact surfaces there is some plastic deformation. The material used by the author was aluminum ST24, which allows a high elastic strain.

A picture of the ring after the relaxation tests were finished is shown in Fig. 5. Direct load test results were given by Fig. 2, Part I. The direct load picture shows a few isostatics normal to the inside boundary in the region of the horizontal axis. They appeared when the load was removed from the specimen, in spite of the fact that it was not maintained for over 15 seconds. They have no meaning in the direct load pattern.

On Fig. 5, the whole surface is covered with isostatics. This was obtained by the refrigerating technique after the last step of loading was finished. The zone beyond isoentatic 40 should be considered as not broken as far as isoentatic values are concerned. The numbers on each isoentatic represent load in thousands of pounds.

The scale of each picture is determined by multiplying the strain sensitivity of the coating by the number representing the standard load (40 representing 40,000 psi in this example) and dividing the result by the reading on the isoentatic lines. This gives the value of the principal strain on all points of that isoentatic when the load applied on the specimen is the standard load.

For the direct load illustration, Fig. 2, Part 1, the scale is:

$$\frac{0.00047 \times 40}{\text{reading}} = \frac{0.0188}{\text{reading}}$$

and for the relaxation method, Fig. 5:

$$\frac{0.00075 \times 40}{\text{reading}} = \frac{0.03}{\text{reading}}$$

The value of the strain sensitivity, ϵ^r, = 0.00075 was obtained from a calibrating cantilever beam, plus correction for the different speeds of loading the cantilever beam and the ring. For the relaxation test the value was: 0.00069 + 9 percent = 0.00075.

The value of ϵ_1 is given in Fig. 2; the value of ϵ_2 is given in Fig. 5. To

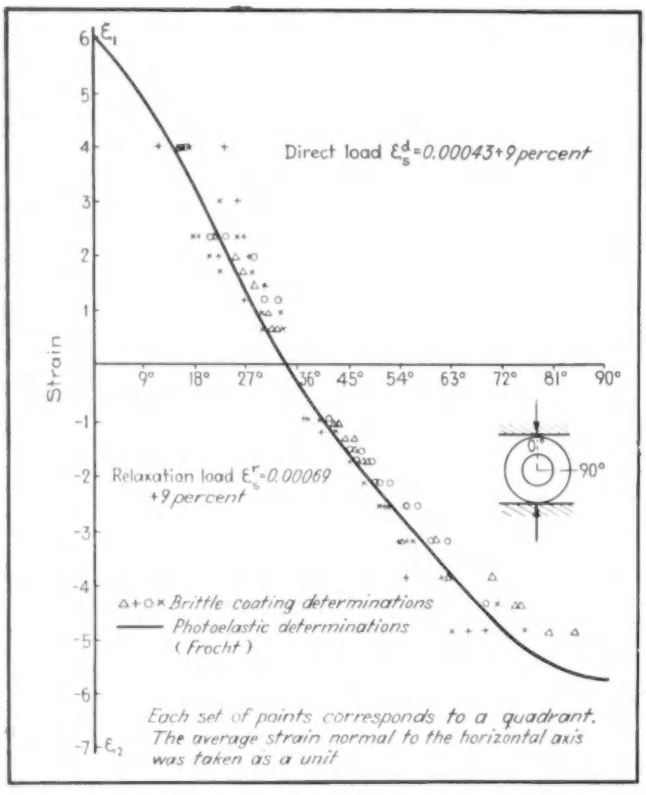
Direct load ε_s^d=0.00043+9 percent
Relaxation load ε_s^r=0.00069 +9 percent
Strain
0°
90°
△+○×Brittle coating determinations
Photoelastic determinations (Frocht)
Each set of points corresponds to a quadrant. The average strain normal to the horizontal axis was taken as a unit

Fig. 7—Strains tangent to the inner boundary in the closed ring.

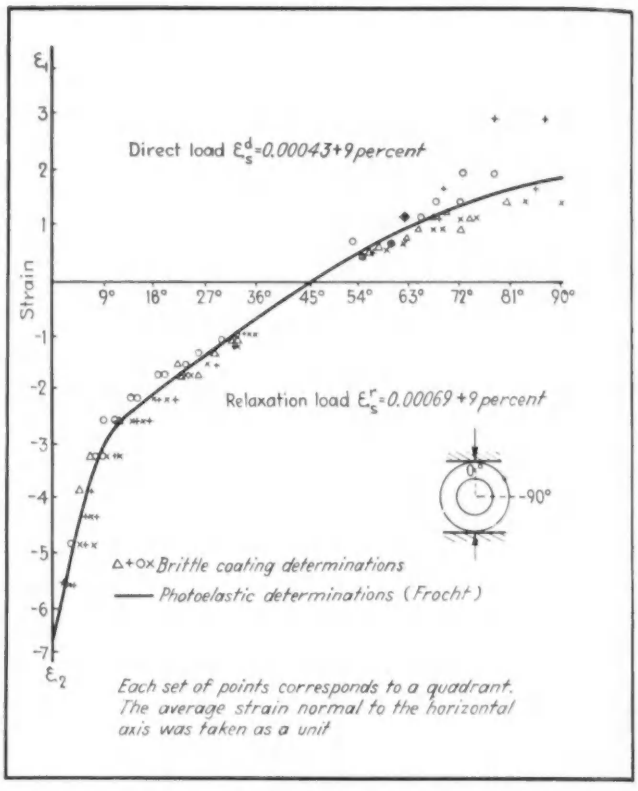
Direct load ε_s^d=0.00043+9 percent
Relaxation load ε_s^r=0.00069 +9 percent
Strain
0°
90°
△+○×Brittle coating determinations
Photoelastic determinations (Frocht)
Each set of points corresponds to a quadrant. The average strain normal to the horizontal axis was taken as a unit

Fig. 8—Strains tangent to the outer boundary in the closed ring.

calculate the values of the principal stresses, σ_1 and σ_2, from these data, determine the number of the isoentatic zones (according to Table I) by superimposing both pictures, as has been done in Fig. 6.

On the boundaries, with the exception of the region near the singular points, and for points of zone 4, the values of the principal stresses may be determined directly by exact formulas. For the other zones approximate formulas given in Table I should be used if the separation between the principal stresses by more accurate means is not necessary.

Consider the point in zone 4 (Fig. 6) determined on the right top quadrant and on the left bottom quadrant, by the intersection of both isoentatics of relaxation 22 (Fig. 5). In the two other quadrants, the value of the isoentatic in the corresponding point is lower (about 20), caused probably by eccentricity of the load. Average value is therefore 21. The strain is:

$$\epsilon_2 = -\frac{0.03}{21} = -0.00143 \text{ in.}$$

a contraction, as indicated by the minus sign.

Direct load isoentatic values for that same point are 32, 30, 28, 26, with an average of 30. The sensitivity of the coating was 0.00047, and the scale therefore is

$$\frac{0.0188}{\text{reading}}$$

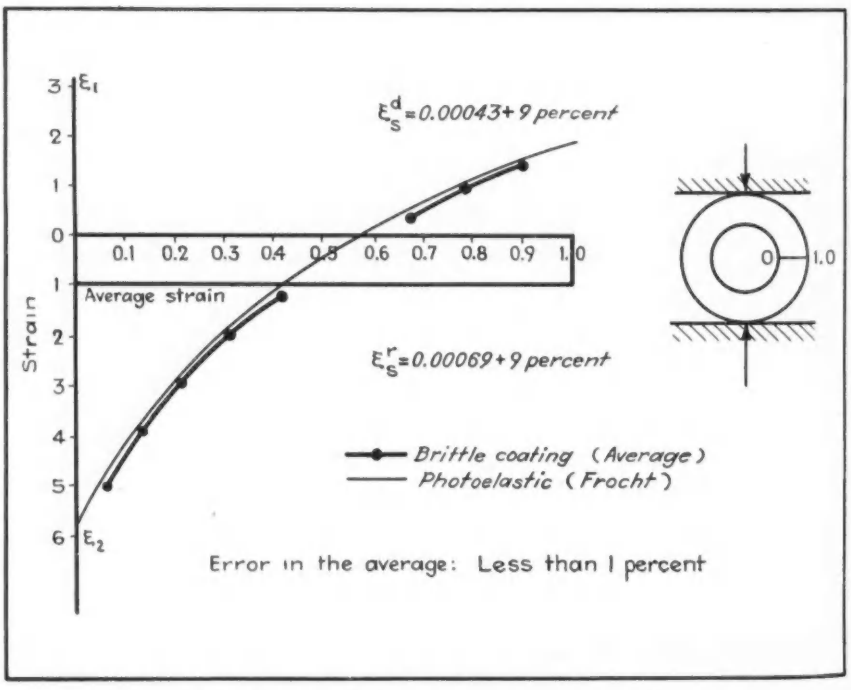

Fig. 11—Average of strains determined by brittle coating method compared to photoelastic determinations. Based on values on the horizontal axis of the closed ring.

The strain on isoentatic 30 is:

$$\epsilon_1 = \frac{0.0188}{30} = 0.00063 \text{ in.}$$

an elongation. Since this point belongs to zone 4 and Poisson's ratio for aluminum is $\eta = \frac{1}{3}$, the formulas to be used are (Table I):

$$\sigma_1 = 1.125\, E\, (\epsilon_1 + \tfrac{1}{3}\, \epsilon_2)$$
$$\sigma_2 = 1.125\, E\, (\epsilon_2 + \tfrac{1}{3}\, \epsilon_1)$$

giving for the principal stresses the values:

$$\sigma_1 = 1{,}690 \text{ psi and } \sigma_2 = -13{,}700 \text{ psi}$$

when the applied load is 40,000 pounds.

These are the stresses acting on one face of the ring. To know what happens on the mid-section plane, they

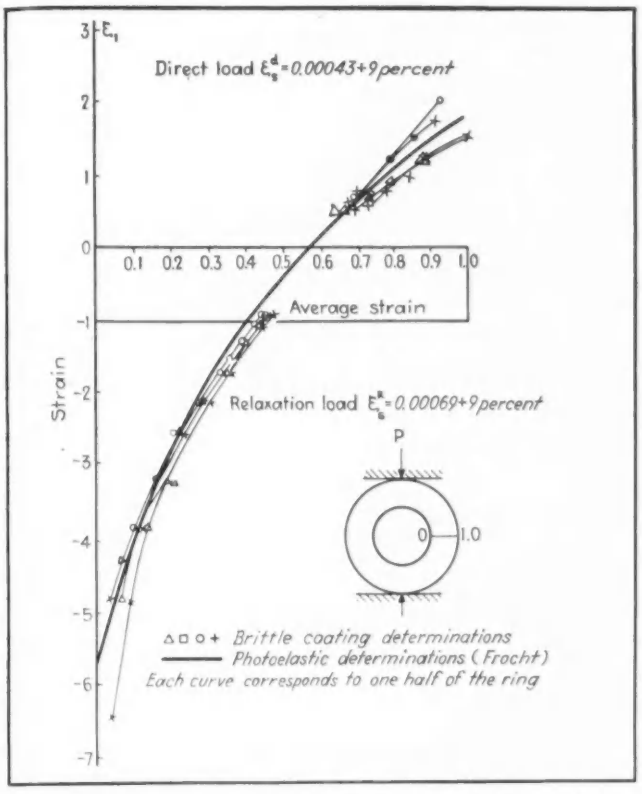

Fig. 9—Strains normal to the horizontal axis in the closed ring.

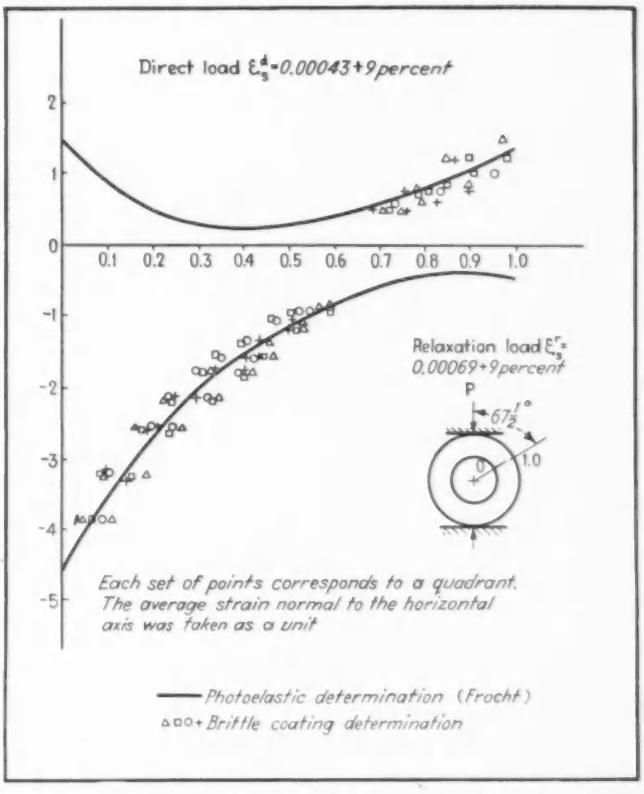
Direct load ϵ_s^d=0.00043+9 percent
Relaxation load ϵ_s^r= 0.00069+9 percent
P
67½°
Each set of points corresponds to a quadrant. The average strain normal to the horizontal axis was taken as a unit
Photoelastic determination (Frocht)
Brittle coating determination

Fig. 10—Strain curves for the 67½ degree axis of the closed ring.

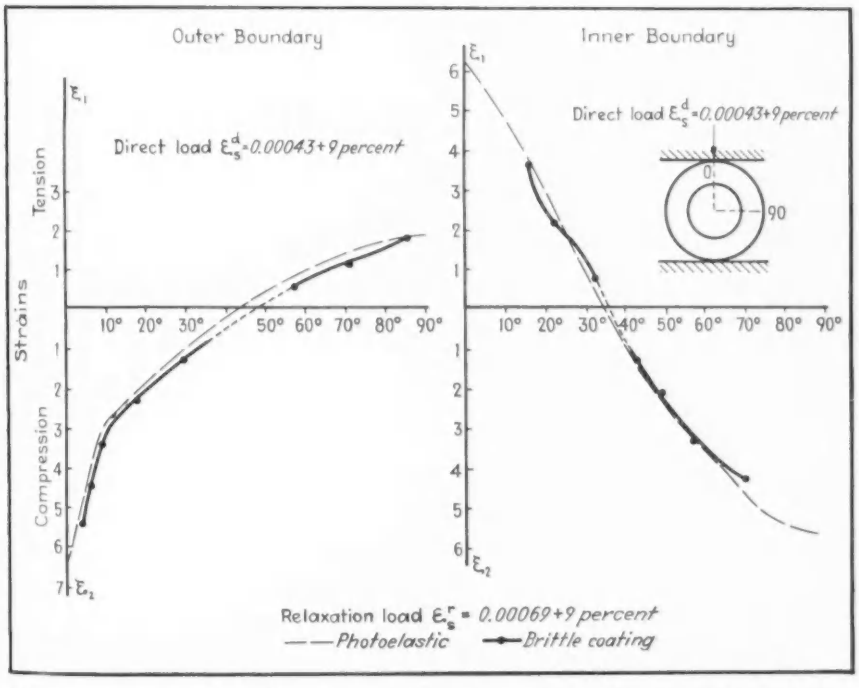

Fig. 12—Average of strains at outer and inner boundaries determined by the brittle coating method compared to photoelastic determinations.

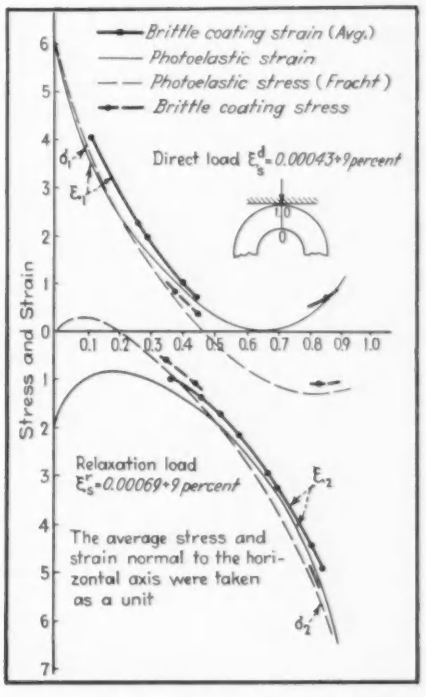
Brittle coating strain (Avg.)
Photoelastic strain
Photoelastic stress (Frocht)
Brittle coating stress
Direct load ϵ_s^d=0.00043+9 percent
Stress and Strain
Relaxation load ϵ_s^r=0.00069+9 percent
The average stress and strain normal to the horizontal axis were taken as a unit

Fig. 13—Stress and strain curves for the vertical axis of the closed ring.

should be averaged with the values obtained for the other ring face.

Check with Known Solutions

M. Frocht, gives the values for the principal stresses on both vertical and horizontal axes, on the boundaries, and on sections located 22.5 deg from the horizontal axis as determined by photoelastic methods on such a ring.

Comparison of the results is made in Figs. 7 through 12. The values are referred to the uniformly distributed strain and stresses on the horizontal axis as a unit. Such curves are independent of the amount of load and elastic constant of the material.

Results obtained with the brittle coating for each of the eight quadrants (four on each face of the ring) are shown in Figs. 7, 8, 9 and 10. The dispersion of the results is generally greater in regions where the coating starts to break first. This dispersion is, however, partially caused by eccentricity of the load.

Photoelastic determinations are com-

pared to the average of the brittle coating determinations in Figs. 11, 12, and 13. The comparison is good. In Fig. 11 the vertical strains are plotted for the points on the horizontal axis of the ring. The average value determined from strain measurements is compared with the calculated average strain. The difference is one percent.

Between abscissae 0.35 and 0.45, approximately on the vertical axis in Fig. 13 the points belong to zone 4, so it was possible to use exact formulas for the calculation of the principal stresses. The values obtained are shown in the figure, and fall close to those determined photoelastically. However, the values of the principal stresses for points between abscissae 0.8 and 0.9, although they agree closely with photoelastic values, do not seem to be reliable. It can be proved that the coating does not break although the strain is tensile and greater than ϵ_y if the strain is parallel to a compressive stress. For instance, for points between 0.0 and 0.1 in Fig. 13 the strain under relaxation is greater than the strain sensitivity, yet the coating did not crack. Therefore, for direct load between 0.8 and 0.9, the stress is not likely to be a compression as shown in the Fig. 13, but a tension Stresses near the point of load application are influenced by the way this load is distributed. In this case, the load was applied through a plane tangent to the ring, and there was some plastic deformation before the maximum load was reached.

General Observations

A. To give brittle coating patterns their correct interpretation it should be kept in mind that sometimes the stress distribution changes as the load is applied. Photoelasticity gives a different interference pattern for each amount of the load. Brittle coatings, however, give an isoentatic corresponding only to the particular loading condition. This happens with contact pressures, where at the time the load is increased the contact surface expands. De Saint Venant's principle makes the importance of this difference negligible at some distance from the zone where the load is applied.

B. Two fundamental properties of the coating have not been studied thoroughly: (1) Dispersion of the strain values given by the coating, (2) the law of failure of the coating. The former is certainly a function of many variables: temperature, humidity, age, and heat-treatment.

A paper on "Law of Failure of Stresscoat" was presented by the author at the spring meeting of the Society for Experimental Stress Analysis. Report is made in this paper of some new important facts which were not known at the time "What Kind of Information Does the Brittle Coating Give?" was finished in August, 1947. One of these facts is that the maximum tensile strain law of failure does not represent accurately enough the failure phenomenon of the coating, not only for the case of pure compression but also for the case of singular points, and for combinations of stresses close to those two extreme cases. For singular points the error introduced by the maximum tensile strain law may be as high as 100 percent.

Although no new analytical formula has been found as yet to express the law of failure, the suggested formulas for some of the zones in Table I, Part I, of this article should be revised to follow closer the new experimental results. The reader should use the tables in this paper more as a method of approach to the problem than as a final answer to all of its complexities.

C. When the brittle coating method is used as a stress analysis method rather than as a stress concentration detector, its sensitivity should be as high as possible. This allows the study of a much wider zone of the surface. To increase the sensitivity it is possible to use either or both of the following procedures: (a) To heat-treat the coating after spraying, or (b) to use a material with higher maximum elastic strain.

Heat-treatments have the advantage of increasing the sensitivity and of decreasing the chances of crazing. Unfortunately, the dispersion seems to increase at the same time. Complete study of these properties requires a close control of the critical variables influencing the behavior of the coating.

D. It seems that the dispersion is higher at the stress concentration points when they are on free boundaries. This is unfortunate. In studies similar to that of the ring, and particularly concerned with stress concentration, it is advisable to coat the inside wall instead of the faces.

E. Close control of the most critical variables that influence the behavior of the coating will be likely to decrease substantially the dispersion of values obtained in these tests.

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Physical Properties of Electrodeposited Chromium

From "Physical Properties of Electrodeposited Chromium" by A. Brenner, P. Burkhead, and C. Jennings, Journal of Research of the National Bureau of Standards, Jan. 1948, pp 31-59.

ONE OF THE ADVANTAGES of electrodeposited metals is the possibility of producing deposits of a given metal with widely different properties by varying the conditions of the parts of deposition. This study concerns density, hardness, tensile strength, Young's modulus of elasticity, ductility, electrical resistivity and stress in the deposit, as well as the effects of heat treatment up to 1,200 C on certain of these properties.

Plating Solutions and Conditions of Deposition. Specimens were deposited from solutions containing chromic acid in concentration from 50 to 500 g per liter together with either (a) sulfate with a weight ratio of CrO_3/SO_4 from 50 to 100; or (b) fluoride with a weight ratio of CrO_3/F of from 20 to 200. The range of plating conditions was as follows: Temperature, from 16 to 100 C; current density from 5 to 30 amp per sq decimeter (amp per dm^2). Current efficiency of the dilute sulfate solution containing CrO_3, 50 g per liter and SO_4, 0.5 g per liter, is about double that of the standard solution. Curves for the fluoride solutions are unusual in that they show maxima at a moderate current density. The maxima occur only for a limited range of fluoride concentration (from 0.8 to 2.0 g per liter).

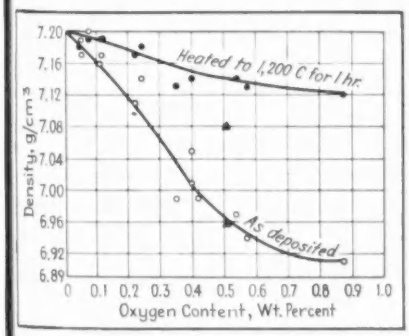


Fig. 1—Relation between density and oxygen content of chromium deposits.

Deposition of Specimens. For most measurements the chromium was deposited on a copper tube which was then dissolved to leave a tube of chromium. The use of a tube has some advantages over a flat specimen: (1) A more uniform current density can be obtained on a tube. (2) The tubular specimen does not distort when the base metal is dissolved because the stresses are evenly distributed. A thin, flat deposit might curl or warp. (3) A thin walled tube can be handled more safely than a flat specimen because it has a shorter length of edge. Thin sheets of chromium are quite fragile.

Factors Affecting Density. Curves in Fig. 1 illustrate the increase in density of chromium as the oxygen content decreases; Fig. 6(b) shows that density decreases as the current density is raised. Because electrodeposited metals are in a more severely cold-worked state than an ordinary cold-worked metal, it might be assumed that the density would be affected. If the lattice expansion of 0.3 percent as compared with chromium annealed at 1,500 C (observed by Woods for bright chromium) were all attributed to internal strain, this would correspond to lowering of the density of chromium by only 0.02 g per cm^3.

The density of chromium increases gradually on annealing. These increases were noted at 450 C and 1,200 C. The density of most deposits after annealing at 1,200 C is still below 7.20 g per cm^3, the value for chromium.

Hardness. Hardness is the physical property of most practical importance. Hardness was measured on a polished cross section of a deposit plated on a copper tube. Thickness of the deposit varied from 0.075 to 0.25 mm. A few check measurements showed that the same hardness was obtained on the cross section as on the surface parallel to the cathode. Measurements were made with the Knoop diamond indenter, using loads up to 500 grams. Hardness of electrodeposited chromium may vary from 300 Knoop to 1,000 Knoop, depending on conditions of deposition. In comparison, the hardness of cast chromium has been given as ranging from 70 Brinell to 130 Brinell.

Effect of Temperature and Current Density. Softer deposits are obtained at low current densities and at elevated temperatures. This statement is subject to modification and restrictions. At a given temperature, deposits of a considerable range of hardness can be obtained by a suitable choice of both composition and plating conditions. Solution temperature, current density and oxygen content affect the hardness

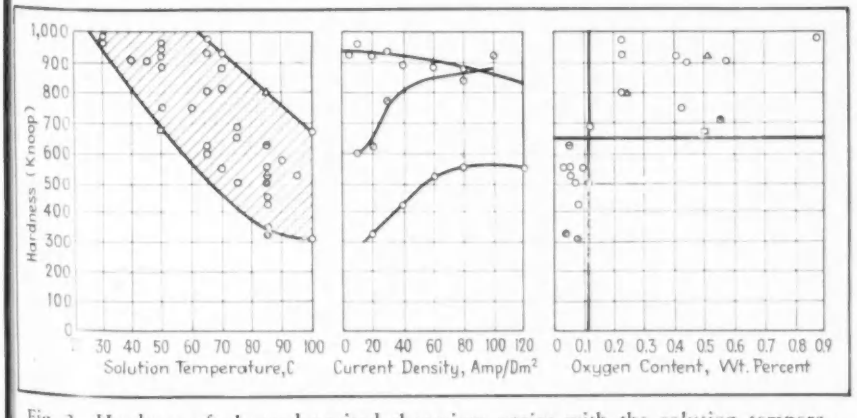


Fig. 2—Hardness of electrodeposited chromium varies with the solution temperature, the current density, and in a more general way, with the oxygen content.

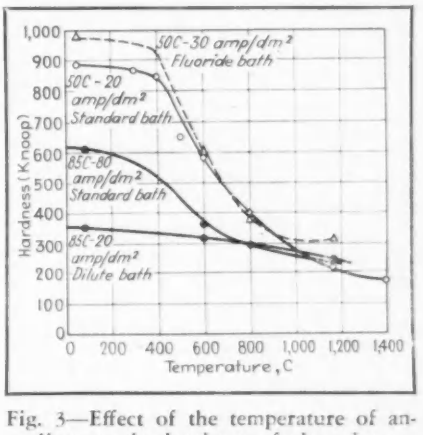


Fig. 3—Effect of the temperature of annealing on the hardness of chromium.

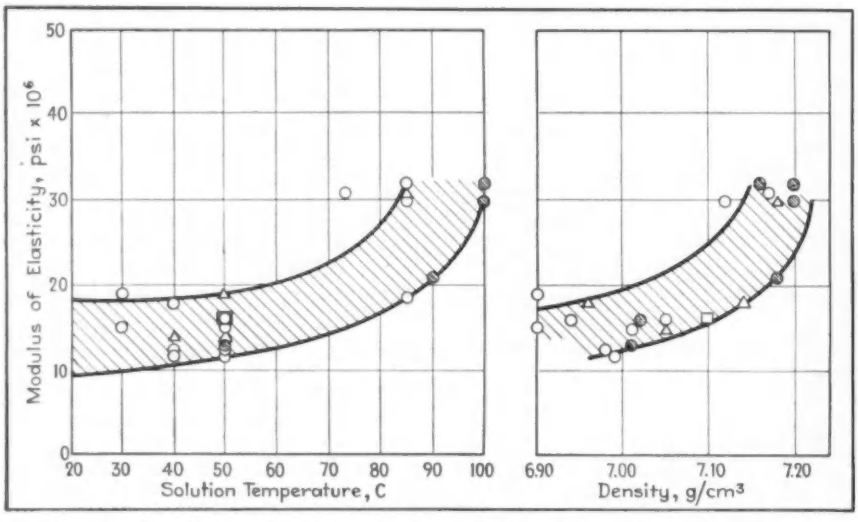


Fig. 4—Modulus of elasticity of chromium as affected by deposition temperature.

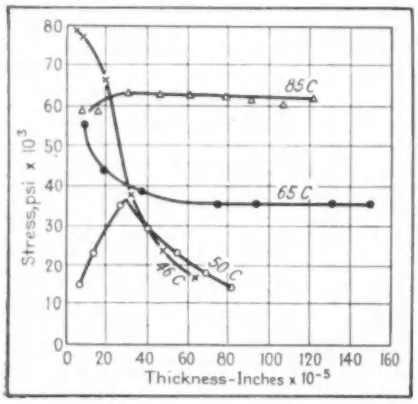


Fig. 5—Relation between the residual stress and thickness of chromium deposits.

of the electrodeposited chromium, as shown in Fig. 2.

Effect of Composition of Bath. As compared with temperature and current density, the composition of plating solution has only a minor effect of the hardness of the deposits.

Effect of Heat Treatment of Chromium. Chromium softens on annealing at high temperatures starting about 400 Centigrade. Hardness in all types of deposits drops to 200—250 Knoop after annealing at 1,200 C for 1 hour.

Relation Between Hardness and Oxygen Content. Oxygen content is one of the most important factors affecting the hardness of chromium. Data in Fig. 2 (c) for all types of deposits shows a definite trend of hardness with oxygen content, but no very precise relationship. According to this figure, if the oxygen content of the deposit is above 0.12 percent, the deposits have a hardness ranging from 650 to 1,000 Knoop, and if below 0.12 percent, the hardness ranges from 625 down to 325 Knoop. It is to be noted that deposits having about the same oxygen content may vary 200 points or more in hardness.

Cause of the Hardness in Chromium. The hardness of chromium probably results from three factors: oxide inclusion, small grain size, and internal stress, of which the first two factors are the most important. Chromium deposits have been shown by X-ray studies to have a small grain size and a high internal stress.

Machinable Chromium. Production of a machinable chromium plate is of interest for special commercial applications. The soft deposit may be obtained from a plating solution containing only CrO_3, 50 g per liter; and SO_4, 0.5 g per liter. At 85 C and 20 amp per dm², the cathode current efficiency is 15 percent, as compared with 8 percent for Gardam's solution.

Tensile Strength and Young's Modulus. Chromium tubes were used, prepared as described before. Because of their brittleness, the chromium tubes could not be directly gripped in the jaws of the testing machine. Grips were provided by inserting a closely fitting steel rod for a short distance into the end of the chromium tube, then cold-welding the rod to the chromium by electrodepositing copper over the juncture. The midsection of the test specimen was protected with "stop-off" lacquer during the plating procedure. The method most satisfactory for determining the modulus in a tubular specimen involves the measurement of the midpoint of a tube supported horizontally at the two ends and loaded at the center. A low power Brinell microscope was used to measure the deflection. Measurements required are weight of load, deflection of the center of tube, length of the tube between supports, and the inner and outer diameters of the tube. Maximum loads used were about 5 lb. The modulus is calculated by the following formula:

$$E = \frac{4\ PL^3}{3\ \pi\ \delta\ (d_1^4 - d_2^4)}$$

E = Young's modulus, psi
δ = deflection, in.
P = load, lb
L = length of specimen, in.
d_1 = outer diameter of the tube, in.
d_2 = inner diameter of the tube, in.

For this formula to hold, the strain must be less than 0.2 percent.

Results of tensile strength—modulus test.

Measurement of the inner and outer diameter of the tube may have the largest effect on the accuracy of the modulus. High uniformity of wall thickness was difficult to obtain, and for this reason reported values can be considered accurate to within only

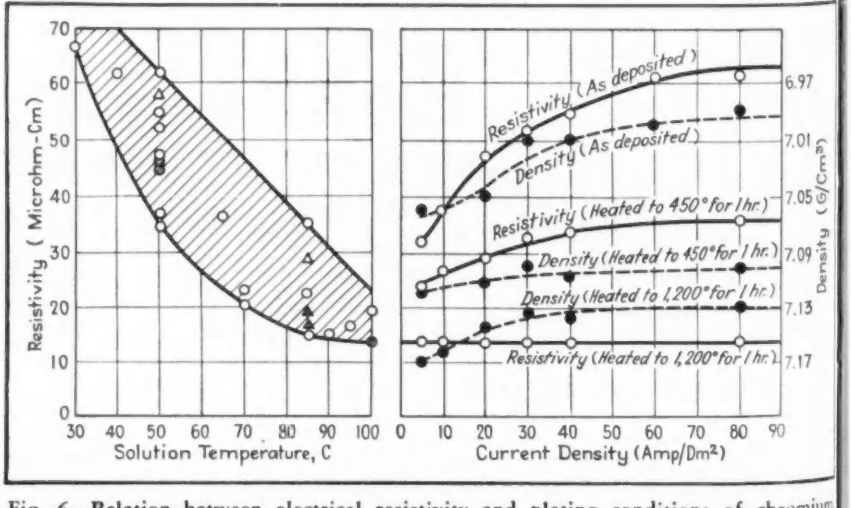


Fig. 6—Relation between electrical resistivity and plating conditions of chromium

about 5 percent. Results are shown in Figs. 4(a), (b). Tensile strength varies from about 15,000-80,000 psi, and Young's modulus from 12 x 10^6 to 33 x 10^6 psi. These values are somewhat erratic and do not show any well defined trend, except that the higher values of both were obtained on deposits made on 85 C or above. Results can best be interpreted on the assumption that they do not represent the true values of these properties, but they are effective values which are dependent on, and hence a measure of, the soundness of the deposits. The presence of cracks and inclusions in the deposits, or pits and nodules on the surface, causes low results and lack of consistency in the measurements. The deposits at elevated temperatures are sounder and hence give higher values of mechanical properties. It is believed that the most reliable value of Young's modulus of chromium is about 36 x 10^6 psi. True tensile strength is probably greater than the highest observed value of about 80,000 lb per sq inch.

Ductility. Measurements showed that ductility is low. Apparently chromium breaks within the elastic limits. Plated metal cannot undergo more than slight flexing without cracking the deposit.

Stress in Chromium Deposits. Metals, particularly chromium, produced by electric deposition are highly stressed. For example, deposits plated at 65 C were relatively free from cracks while on the copper base; but when the copper base was dissolved, some of these developed a network of cracks and fell into fragments. Troublesome cracking of the high temperature deposits can be largely eliminated by using a dilute plating solution or one of the solutions (described in the paper) containing fluoride instead of sulphate. Results obtained by deposits made at different temperatures are shown in the Fig. 5 chart.

Electrical Resistivity. This may be an index of the character of the deposits, but it is not of much practical importance in itself. Fig. 6 gives the data for numerous temperatures and current density.

Summary. As the properties of various types of electrodeposited chromium approach a common value after the chromium has been heated to 1,200 C, the properties of this annealed chromium may be considered to be those of pure chromium. Values of these properties are summarized as: hardness—200 Knoop; density—7.20 g per sq cm; Young's modulus 36 x 10^6 psi; tensile strength—70,000 psi; resistivity—13.0 microohms—cm. Some deposits obtained at temperatures between 85 and 100 C have physical properties close to those of annealed deposits. The inference is that these deposits are the purest and soundest and are most likely to be satisfactory for any purpose other than those requiring high hardness.

Properties of Trailing Electric Cables

From "Essential Characteristics of Design and Materials for Mine Trailing Cables" by G. J. Crowdes, Simplex Wire and Cable Co. presented at 1948 AIEE General Meeting, Pittsburgh, Pa.

DESIRED CABLE PROPERTIES include: (1) Flexibility, both in ease of bending and ability to withstand many bends; (2) wear resistance of outer jacket; (3) heat resistance; (4) crushing and impact resistance; (5) chemical stability; and (6) flame resistance. In addition, the cables must have sufficient strength to withstand reeling, unreeling, sharp pulls, twisting, flexing, and bending.

Some common cable types, usual uses, and important design features are included in Table I. Table II compares three materials used for cable jackets.

Table I—Comparison of Different Types of Common Cables

Cable	Usual Use	Service Conditions or Hazards	Some Important Design Features	Remarks
Single conductor	Locomotives Motor leads	Reeling Pulling Runovers Twisting	Good adhesion between insulation and conductor and insulation and jacket	Sheaves and guides in service should be placed to reduce twisting.
2 Conductor, flat twin types W & G	Loaders Cutters Shuttle cars Locomotives	Reeling Pulling Runovers Twisting Crushing & Impacts	Good adhesion of insulation and jacket	Good runover resistance. Economical of space on reels. Type G has flat ground wire between conductors. Sliding of conductors when bent on major axis not recommended.
2 Conductor, concentric	Locomotives Shuttle cars	Reeling Pulling Runovers Twisting	Good adhesion between insulation and conductors and insulation and jacket	Not as good on runovers as flat twin. Flex-life less also twisting should be held to a minimum.
2, 3, 4 conductor, round Types W and G	Cutting Loading Shuttle cars	Reeling Pulling Runovers Twisting Crushing & Impact	Good adhesion between jackets	Have good flexlife and can stand runovers well. Type G has ground wires in interstices. Not as economical of space as twin or concentric.

Table II—Typical Properties of Jacket Compounds For Mine Trailing Cables

Property	Neoprene	Buna S	Natural Rubber
Initial tensile, psi	3,000	2,800	4,000
Initial elongation, percent	500	350	500
Aging	excellent	excellent	good
Heat resistance	good	excellent	fair to good
Tear (ASTM), lb per in	110	55	55
Abrasion	excellent	fair	very good
Brittle point, C	−40 C	−50 C	−70 C
Flame resistant	yes	no	no
Oil resistant	yes	no	no
Light checking	excellent	good	good

Table 1—Safetying Devices for Nuts and Bolts

Safetying Device	See Fig. 2	Advantages	Disadvantages
FORM LOCKING			
Castellated nut with cotter pin		Reliable safetying. Bolt itself need not be safetied.	If cotter pin hole does not have correct position, safetying is not possible. Binding at slots of crown when nut is screwed on. Too much time if accessibility is bad. Large number of cotter pin sizes of different length and diameter must be kept in stock. Expensive (slotting and drilling of castellated nut takes 1.6 to 1.8 times as long as plain hex nut).
Castellated nut with wire		Wire used from roll, no stock problems. Wire will also safety a loose bolt.	Time used to twist wires. Poor appearance. Possibility of a cut wire falling in mechanism. Possibility of error in wiring (incorrect wiring allows nut to slack off).
Safetying with metal sheets		With good accessibility, a useful, quickly installed safety device.	Bolts must be safetied separately, otherwise safety has no effect. Long time to safety, when accessibility is poor. When sheet is used several times, a bent part may break off.
Formed parts and springs	(A)-(G)	Safetying good when design fits need.	No standard parts. Often complicated and expensive.
Union nuts with wire safetying			Difficult and expensive.
Union nuts with spring wire formed part	(H)	Easy to handle.	Expensive.
JAMMING SAFETY DEVICES			
Jam nuts		Simple.	Great height, heavy, expensive.
Nuts with fibre safety	(I)	Simple and convenient. Nut and safety are single unit.	Cannot stand repeated unscrewing. Sensitivity to heat (good only below 100 C)
Nuts with rolled-in platelets		Resistance to oil and heat.	Safetying action lost if platelets are plastically deformed.
Spring washers with ends bent up and plain		Simple in use.	No good with repeated unscrewing. Cuts groove in seat, bite and spring action become weaker. Weakens at high temperature. Injures light metal seats unless used with extra washers.
Toothed spring washers	(J)	Simple, convenient.	Same as above, but in addition, lessened spring action.
Pal nuts	(K)	Simple, light	Damages bolt thread. Sometimes not possible to unscrew nut.
"Contra" nuts	(L) (M)	Simple, convenient. Nut and safety are single unit. Useful at temperatures, where fibre fails.	Moment of friction practically constant. Difficulties in production in maintaining constant strength in spring. Difficult in installation due to high friction moment.
Ratchet nut	(N)	Simple, convenient. High moment of friction remains constant.	Bolts must be slit. Cannot be used interchangeably. Construction and finishing complicated. Carrying capacity of thread lowered by cutting thread.
Slit, spring—type nuts	(O)-(Q)	Simple to use.	Difficult to install due to high friction moment required. Certain designs expensive to manufacture.
Safetying by difference in thread pitch between nut and bolt		Cheap to manufacture. Simple to install.	Bolts are not interchangeable with standard. Abnormal tools and gages needed. High moment to overcome friction on installation.

Safety Devices for Nuts and Bolts

From report on "Safety Devices for Nuts and Bolts" by Hans Schaefer; Muenchen, Germany, April 1944. Translated by Air Documents Div., Air Materiel Command, Report F-TS-2753-RE.

IN GENERAL, absolute safety against loosening does not exist, although all safety devices for nuts and bolts protect against complete loosening and loss of parts.

Safety devices for nuts and bolts may be classified as: (1) Form locking; (2) jam locking. Form locking devices depend on mechanical interference of parts for safetying action. Jam devices depend on friction developed between nut and bolt. Shown in Fig. 2, are a number of form locking and jamming devices. The advantages and disadvantages of these types are given in Table I. A measure of performance for jamming devices is the friction moment (see Fig. 1) required to tighten them.

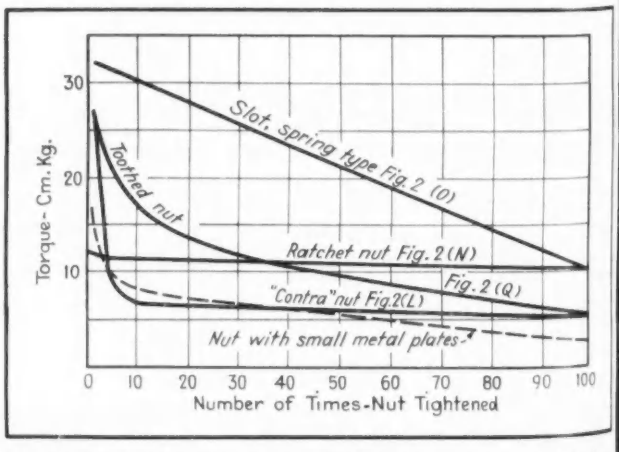


Fig. 1—Tightening moment needed to overcome nut friction

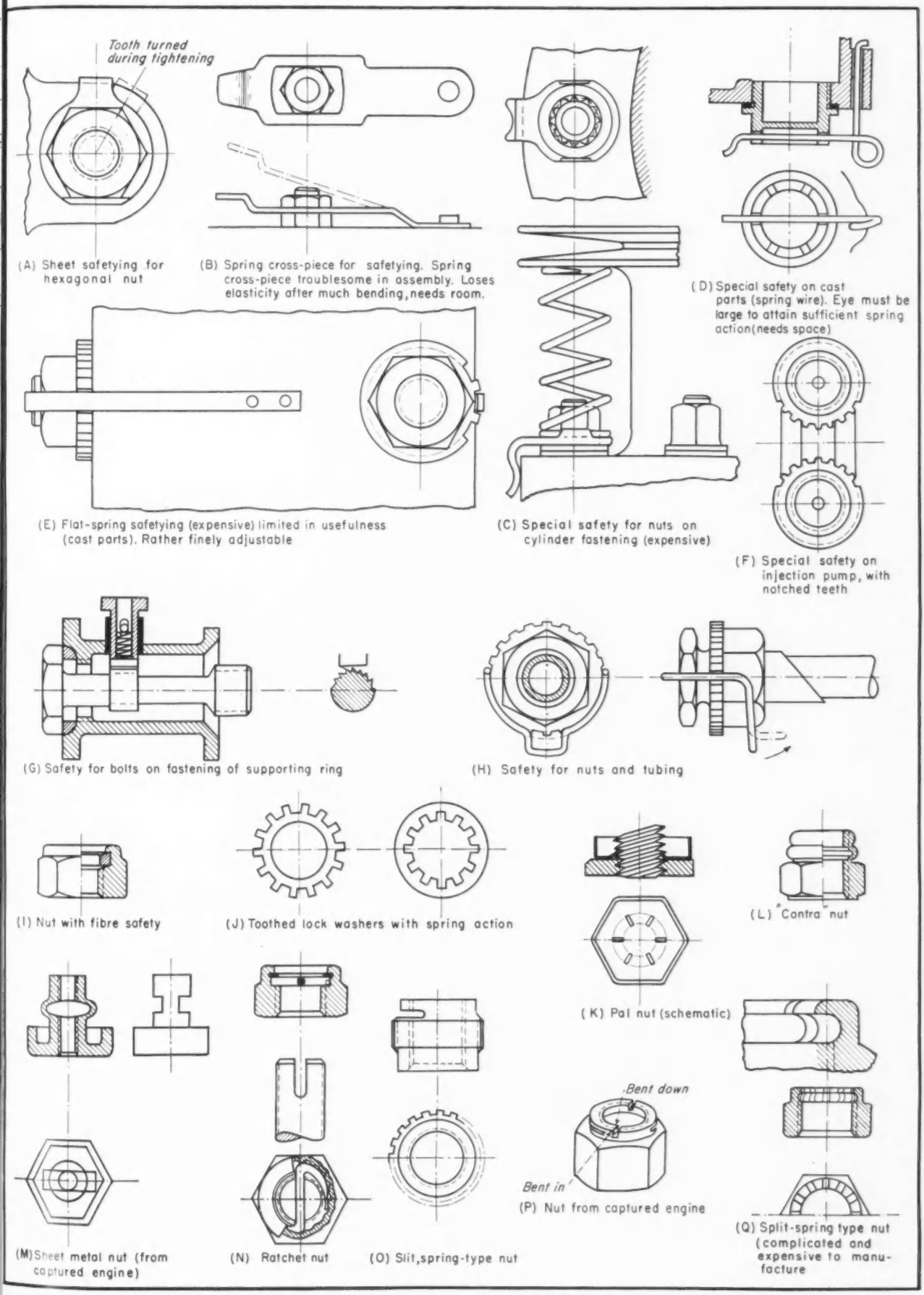

Tooth turned during tightening
(A) Sheet safetying for hexagonal nut
(B) Spring cross-piece for safetying. Spring cross-piece troublesome in assembly. Loses elasticity after much bending, needs room.
(D) Special safety on cast parts (spring wire). Eye must be large to attain sufficient spring action (needs space)
(E) Flat-spring safetying (expensive) limited in usefulness (cast parts). Rather finely adjustable
(C) Special safety for nuts on cylinder fastening (expensive)
(F) Special safety on injection pump, with notched teeth
(G) Safety for bolts on fastening of supporting ring
(H) Safety for nuts and tubing
(I) Nut with fibre safety
(J) Toothed lock washers with spring action
(L) "Contra" nut
(K) Pal nut (schematic)
Bent down
Bent in
(P) Nut from captured engine
(M) Sheet metal nut (from captured engine)
(N) Ratchet nut
(O) Slit, spring-type nut
(Q) Split-spring type nut (complicated and expensive to manufacture

Fig. 2—Safetying devices for nuts and bolts. Safety devices for new applications must be tested before putting them in service.

LARGEST Bausch and Lomb optical comparitor in use at NYU Gage Laboratory to discover accurate dimensions of razor blade as measured from the centerline. Axes on ground glass screen, large magnification and vernier adjustments make possible measurements to one ten-thousandth laterally and one minute angularly.

University Maintains Contact with Industry

New York University College of Engineering is helping solve industrial gaging problems and teaching latest methods in modern laboratories.

A PREPARED INDUSTRY can shorten the mobilization cycle in time of emergency and this was the topic at the recent Ordnance Gage Conference held at New York University. The College of Engineering and the New York Post of the American Ordnance Association joined to conduct this conference to discuss problems incidental to ordnance production under wartime conditions.

This was the latest step of the university in its efforts to reduce the difficulties encountered during a period of rapidly expanding industry. During such times too many things are changing at once, and manufacturers begin to wonder if they will produce anything. Designs change, schedules change, quality standards change and priorities are not constant.

Aggregate opinion of this conference was that flexibility of business enterprises is necessary and that flexibility can be best achieved by training. Dr. J. M. Juran, Professor of Administrative Engineering, NYU, emphasized that training necessary to prepare for an emergency will pay off immediately. Management problems are always the same: How to achieve uniform production flow; how to measure a day's work; how to control quality to do the job right the first time, and how to save manpower.

Some of these problems can be solved in a gage laboratory and others can be reduced by inter-company discussion. Primarily, all personnel connected with production should be instilled with the idea of making a part meet specifications instead of making it to get by the inspector. In step with this is the industry shift to giving machine operators gages that are accurate. As pointed out by C. W. Kennedy, Quality Control Engineer, Federal Products Corp., the production man should have the most discriminating gage. He is making parts and should make them right—inspectors just check parts and do not need more accuracy.

The NYU Gage Laboratory was established through the cooperation of the school and the New York Ordnance District. In accordance with U. S. Army Ordnance objectives, the laboratory is equipped to handle all phases of practical gaging problems. The laboratory facilities are available for making precise measurements in industrial research problems and are continually used in large research projects carried on by the university. Subjects in which accurate measuring is necessary, range from experiments to determine eye size changes produced by diet changes, to advanced studies of jet motor action.

Largest single duty of the laboratory at this time is the training of most engineering undergraduates in the use of gages; their advantages and limits. In many instances students help to solve problems submitted by industrial concerns. Students leave this lab with basic concepts of industrial accuracy, and with knowledge that tolerance limits are rapidly approaching each other.

Ordnance officials have said that the huge investment in expensive gages would be best expended if the gages were worn out in teaching students, graduates and key industry personnel.

During World War II, the NYU Gage Laboratory was used in checking gages, for checking masters, jigs and

products, and for training inspector supervisors. The laboratory staff is constantly in touch with industry and keeps up with the latest production and gaging methods. In another emergency, the experienced staff can draw on industrial knowledge and student teaching practice to process large quantities of inspectors. At the same time they will be aiding industry with their accurate equipment.

The laboratory can check accuracy of simple or multi-check gages, can use light waves in making accurate plane measurements, and has complete sets of gage blocks and thread measuring wires.

Gage Laboratory facilities are also used for training supervisors and key men in industry. Such men, while interested in the "how" of gage use, are more concerned with the "why". For them, advanced courses are planned in standardization, plan for interchangeable manufacture, control of accuracy of gage systems and control of quality at the source.

These men are shown that industry is really the laboratory and it is there that theories must be proved. They are trained to think of gaging as a check on the manufacturing process rather than as a sorting out of good parts from bad. The manufacture of ordnance parts calls for the most exact plan for interchangeability because the parts are not assembled until they reach the firing line.

The Ordnance Gage Laboratory, backed by government funds and working under contract with the U. S. Army Ordnance Department, is doing much to interest industry in preparedness for any future emergency. However, the university is doing other work to coordinate planning efforts of industry, research organizations and government departments.

Management round table discussions on work simplification and quality control have brought together experts from many industries. The round tables are ten meetings held one day a week for ten weeks. Not more than 15 men from industry, and university personnel, discuss problems they are currently facing.

Attendance records indicate that these meetings are helpful to plant managers, operating executives, quality managers, chief inspectors, chief engineers and product engineers. Round tables discuss current practices and work together to solve actual problems submitted by the conferees.

New York University, through these activities, is reducing the gap between classroom theory and practical application for its students; is removing some of the mystery that originally surrounded mangement engineering, and is helping to keep industry flexible and well-trained.

STUDENTS working on actual industrial problem at NYU Gage Laboratory under supervision of its director, Professor W. A. MacCrehan. Laboratory serves double purpose of student instruction and nucleus for wartime gaging centers.

Recent Survey Shows Engineers Development

GROWING TREND OF SOCIETY to recognize importance of the engineering profession as a vital part of community and economic life has been shown by a survey of 17 leading engineering colleges. The survey, handled by Brown Instrument Co., Division of Minneapolis-Honeywell Regulator Co. and discussed by George M. Muschamp, vice president in charge of engineering, presents appointments of engineering leaders to government, military and industrial committees as evidence of public recognition of engineering profession.

Originally, the survey was intended to discover whether there would be a sufficient supply of engineers to meet increasing demand, or whether supply would exceed demand. It was also hoped to discover what was being done to close gap of inexperience that exists between book knowledge and practical application.

Colleges surveyed show student body increases ranging from 50 to 325 percent over 1941 figures for similar courses. Including summer students, 6,441 engineering degrees were granted in 1947; an increase of 98 percent over 3,250 graduates in 1941. Current enrollment indicates 1948 graduates will show 104 percent more graduates than 1941. Because present classes contain many students whose courses were interrupted by war service and industrial needs for trained engineers are still increasing, oversupply will not be an immediate problem.

Colleges and industry are cooperating to reduce gap between classroom study and industrial work. Colleges are placing increased emphasis on desirability of their staffs to retain active contact with industry problems. Curriculums are being expanded to in-

clude more practical work and many industries are instituting post-graduation courses. Brown Instrument Co. conducts classes and discussion groups throughout the country and maintains a school where new men and customer users of Brown instruments are trained. This is representative of many similar industry programs.

The survey shows that war caused previously unreached understanding between the three main technical groups. The groups are best described as: (1) Theorists, discoverers of basic knowledge, (2) determiners, engineers determining practical application of fundamentals, and (3) practitioners, the production engineers. Up to the war there was technological class distinction between the groups and varying degrees of misunderstanding. Each of the three groups was forced to understand purposes and importance of the other two groups because of war pressure.

Mr. Muschamp concludes that, "If the survey has done nothing more, it has brought to light the encouraging developments which are occurring in the engineering profession. Summarized, they are the improved conditions including the increasing number of students who are entering the engineering field, the expanding acceptance of the engineering method within industry and government, the gradual closing of the gulf between the graduate's college life and his entry into the commercial world, the increasing civic consciousness of the engineer, and the pulling together of the previously loose and unrelated activities of the theorist, the determiner and the practitioner."

To avoid future lack of men trained of the three main engineering groups, these groups should work in cooperation, but should not lose their separate identities.

Micro-Wave Research Tower Recently Completed

To carry out complex research in the micro-wave area, to develop communication uses for micro-waves and to investigate radar systems, the Federal Tele-communication Laboratories recently dedicated a micro-wave research tower at Nutley, N. J. Federal, research unit of International Telephone and Telegraph Corp., has been actively pursuing micro-wave studies for many years and now predicts world-wide links of micro-waves used to carry telephone, telegraph and television.

Basically, the micro-wave field has opened large channels in the radio spectrum that was considered hopelessly overcrowded. These new channels are wide and are capable of handling a large number of telephone or telegraph simultaneous communications, rapid signals such as used in aerial navigations, or a limited number of television links.

A new method of transmissions, Pulse Code Modulation, first conceived in ITT System Laboratories, avoids progressive deterioration of speech quality as distance is increased. It is now possible to engineer circuits of this type that can extend as far as limits of land.

It is believed that micro-wave links are better adapted to spanning comparatively undeveloped regions than coaxial cables. Radio links require partly attended repeater stations every 30 miles, while cables must have continuous right of way with repeaters every 7 or 8 miles. Micro-wave links do not use as large quantities of critical materials—lead, tin and copper—as cables, and would be easier to maintain and police during periods of emergency.

MICRO-WAVE research tower has roof working area with scanning radar antenna, three enclosed working areas and elevator. Twin disks at upper left are sending and receiving points for micro-wave link to Telegraph Hill, N. J.

The 300 ft., aluminum-sheathed tower has three inclosed landings for research purposes and several interior platforms for installation of equipment. Seventy-five percent of the tower weight is concentrated between the 212 and 300 ft. levels. Weight concentration and requirement that tower top deflection not exceed 10 in., necessitated unique construction. Requirement for small deflection was set because a greater variation would introduce focussing difficulties. Micro-waves travel on line of sight and can be accurately directed.

Other studies to be followed at the tower include distance measuring radar and two-color aided radar. The Distance Measuring Equipment (DME) is a radar device that provides continuous and accurate measurement of distance from an airplane to fixed ground beacons. This apparatus may be incorporated in aerial navigation and traffic control systems now under consideration.

Shown publicly for the first time during dedication ceremonies two-color radar is expected to bring new efficiency to airport traffic control. The system is being developed by Federal under contract from the Watson Laboratories of the Air Material Command, Redbank, N. J.

With a scanning rate of once per second, 6 to 10 times faster than present antenna rotation, the new equipment shows a more continuous scene on viewer screen. Another advantage of this new system is improvement of echos by "aided" radar. Clarity and range of ordinary radar picture has been increased by providing airplanes with a "responder" that returns an echo 10,000 times stronger than actual echo. Beside increasing range, stronger signals make it possible to eliminate large portion of ground clutter.

Natural and artificial echo pips can be optically combined for viewing on one radar scope. Aided response pips appear as brilliant green dots and natural echoes appear as amber spots. A plane not equipped with a secondary radar responder—or an enemy plane—stands out clearly.

Washington Notes

Supersonic Wind Tunnel Reaches Mach Number Four

High-speed flexible-throat supersonic wind tunnel (PRODUCT ENGINEERING, December 1945, page 856) has recently been dedicated at Aberdeen Proving Ground, Md. During dedication ceremonies, this wind tunnel operated with a wind velocity four times that of the speed of sound.

Conceived in 1939 by Professor von Kármán the design of this tunnel is the first incorporating a method for changing throat area without making it necessary to change throat section component. The vertical sides of this wind tunnel are stationary plates. The top and bottom sections are ¼ in. spring steel plates that can be formed to previously calculated contours by use of screw jacks. The jacks are positioned by a series of accurately ground cams. The shape of the throat must be accurate to within 0.001 in. and models tested in this tunnel must be machined to within 0.002 in. This is necessary so that unwanted shock waves are not generated. Moving plates are sealed by inflated rubber tubing.

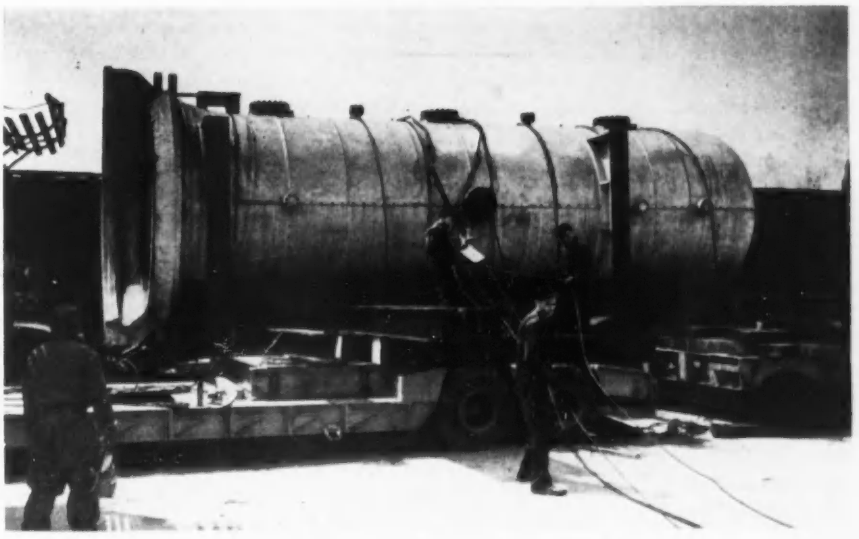
Supersonic wind tunnel investigation will be greatly speeded through use of the flexible throat. No longer will it be necessary to hold up work until a large batch, requiring the same wind velocity, has been gathered. Now, tests can be run as need arises without regard to Mach number.

Non-Inflammable Hydraulic Fluids Announced by NRL

First successful non-inflammable hydraulic fluids have recently been announced by scientists at the Naval Research Laboratory, Washington, D. C.

Called "hydrolube" fluids, these liquids are water-based and completely avoid fire hazard resulting from use of petroleum-based fluids in hydraulic systems. Specifically developed as a safeguard against fire in aviation hydraulic systems, these fluids have been rigorously tested for two years in navy planes. The Civil Aeronautics Administration is currently testing hydrolubes for possible commercial airline use. The Navy's Bureau of Aeronautics (which has sponsored the hydrolube development along with the Office of Naval Research) has approved the water-based fluids for use in future Naval aircraft.

These fluids are adaptable to commercial hydraulic systems where there is danger of fire such as in foundrys and machine shops. They are finding use in die-casting equipment, hot metal linotype equipment and processing equipment in steel mills. Costing from $2.50 to $3.00 per gal., several grades of hydrolube fluid are being manufactured commercially.



New Underwater Ordnance Testing Tank

THIS LARGE STEEL PRESSURE TANK, which will be used to simulate hydrostatic pressures encountered by underwater ordnance, has recently been manufactured by the Babcock and Wilcox Company of Barberton, Ohio, for installation in the Naval Ordnance Laboratory's Mechanical Test Bldg. at White Oak, Md.

Although designed to withstand up to 2,000 pounds of pressure per sq. in., the tank is expected to be operated normally at pressures approximating 1,000 pounds per sq. in. It will be used exclusively in testing heavy ordnance, and pressure may be applied either through use of air or water. In either instance, however, serious engineering problems will be encountered. It is expected that these will be solved by members of NOL's Mechanical Evaluation Division long before completion of the building in which the tank is to be installed.

Cylindrical in shape, the tank is about 38 ft long and 9 ft in outside diameter. Weighing 105 tons, it is constructed of steel, with an average thickness of approximately 5 in. Its capacity is 55 tons of water. This with pressure applied—due to elasticity of the tank and compression of the water—will leave about 10 cu ft within the tank unoccupied. The tank was assembled from four individual cylindrical sections which were welded together to form one structure. Welds have been submitted to latest metals testing procedures, including X-rays, to insure that they will hold up under large pressures.

The tank will be equipped with a door weighing 40 tons. Hydraulically operated, this door during actual pressure tests will be sealed with a pressurized gasket. With this type of sealing it is expected that pressure leakage from the tank during operation will not exceed one cubic foot per hour at normal operating temperature.

Scientists—Draft or Defer?

The National Security Resources Board (NSRB) is going to be one of the controlling agencies in drafting or deferring scientific personnel under the draft law.

Present bills don't say anything specifically about scientific deferments. What the law will do, however, is direct the president to handle such problems administratively. The thinking of Congress is this: Local draft boards handled deferment problems well during the past war. However, they are not equipped to decide special questions of deferring scientific manpower. On the other hand, there is no way deferment provisions can be written into the law. Law makers would like to see special appeal boards set up to handle scientists.

Senate version of the draft law said: "The Congress further declares that adequate provision for national security requires maximum effort in the

fields of scientific research and development, and the fullest possible utilization of the Nation's technological, scientific, and other critical manpower resources". The House bill was not this specific, but contained same basic authority.

Both Houses agreed that NSRB should be the agency to set up policies for best utilization of nation's manpower. They also agree that NSRB recommendations, approved by the president, can provide sound deferment criteria for scientists.

One thing is sure; there will be no blanket deferments of scientific people. Each man will be handled on an individual basis.

House Committee Plans Synthetic Liquid Fuel Industry

First detailed blueprint of government plans for priming the costly, slow-growing synthetic oil industry has been written by the House Interstate and Foreign Commerce committee. It re-wrote the Wolverton bill, approved it unanimously and hopes to get it through the House this session.

The new goal is far from the 9 billion dollar, 2 million barrels per day program pictured by Secretaries Forrestal and Krug as the desired goal. The committee wants a technically advanced, easily expandable foundation for a full-scale emergency industry. Total cost in loans to private industry and government-owned plants not to exceed 350 million dollars; production to be about 30,000 bbl per day.

Since private industry is building commercial plants for production of synthetic from natural gas, the committee feels no government backing is necessary for this type

How Much Power for Science Foundation Director

The House of Representatives recently held two-day hearings in efforts to answer this dilemma. The Science Foundation bill is still having troubles in passing Congress.

Earlier, Senate sponsors of the bill claimed they'd reached agreement with the Administration, but the Director of the Bureau of the Budget, speaking for Administration, strongly called for including a provision that was struck out by the Senate. This stated in so many words that the Director of the Foundation would exercise powers of the Foundation within general policies set by Foundation members. Senate sponsors, who struck out such a provision they had originally included, held that it was enough to state that the Director shall be the chief executive officer of the Foundation.

Net result has been to again raise question of Presidential veto. The Budget Bureau held that the authority for making contracts and grants, as the bill passed the Senate, would rest completely with the 24-man Foundation. Congressmen were reminded that this was a major presidential criticism when vetoing last year.

Insulators Used to Control And Amplify Electric Current

A RADICALLY NEW METHOD of controlling flow and amplification of electric current—one that may have far-reaching influence on electronics—has recently been discovered at Bell Telephone Laboratories.

The method is based on a discovery that when beams of electrons are shot at an insulator, in this case a diamond chip, electric currents are produced in the insulator that can be several hundred times as large as the current in the original electron beam. Essentially it means causing an insulator—which by definition will not conduct electricity—carry considerable amounts.

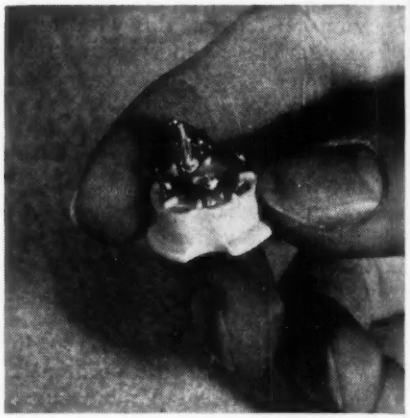
If certain engineering problems can be overcome, the techniques may lead to the development of important new electron tubes. For example, Bell Lab engineers feel this technique might profitably be applied to development of an entirely new means of obtaining high amplification.

This development is also expected to be of considerable theoretical value because it provides a new and powerful tool with which scientists hope to learn more about the fundamental structure of solid matter and how it behaves under the impact of electrons.

Methods of amplifying currents in gas or vacuum tubes have been known for about 35 years, but this is the first time that it has been done in solids. Such an accomplishment offers a wide variety of possible applications and opens an entirely new field of electronics for investigation.

Since the technique was discovered by purposefully bombarding diamond chips with alpha particles, the relatively heavy, positively charged bits of matter shot off by radioactive substances, improved laboratory tools for detecting and counting alpha particles may soon be available. Such a device would do essentially the same thing as the familiar "Geiger counter" but would be smaller, require lower operating voltage and have a faster counting rate.

One of the most important features of this new technique is that the induced currents are produced within short times. Time required is so brief that thus far it has been impossible to measure it. The investigators are certain, however, that it is less than one ten-millionth of a second.



MOUNTED in a ceramic tube socket and bombarded with a beam of electrons, a tiny diamond chip yields electric currents as much as 500 times as large as the current in the original beam.

Aberdeen Proving Ground Adds Stratospheric Facility

Actual firing tests of aircraft guns and ammunition under simulated atmospheric conditions encountered in combat flight can be run in the new chamber recently dedicated by the Army Ordnance Department at Aberdeen Proving Ground, Md.

The new stratospheric facility, which has been under construction since July 1945, is the largest firing chamber in the world capable of simulating both changes in temperature and atmospheric pressure occasioned by fast aircraft. Starting at 70 F above zero and sea level pressure, aircraft weapons as large as the 105 mm cannon can be fired as temperature and pressure are varied to simulate an aircraft ascending at the rate of climb of 5,000 ft per min, up to 50,000 ft altitude arriving at a temperature of 70 F below zero and a pressure of about 1.7 pounds per square inch.

The facility consists of an insulated steel firing chamber, heavily rein-

forced, in which guns and operating personnel are located, and is connected by a firing port to a concussion chamber. The concussion chamber is a large heavy steel pressure chamber into which the gun muzzle extends and which absorbs concussion caused by firing. Rear of this chamber contains 25 ft of sand and armor plate 3 in. thick to stop large high velocity shells. Firing chamber and concussion chamber can be independently controlled in both temperature and pressure. Over 600 hp of refrigeration equipment and vacuum pumps maintain rarified air condition at 50,000 ft and sub-zero temperature of 70 F below zero while aircraft cannon are fired automatically.

Instruments record velocity of each round from machine guns firing over 1,000 rounds per min, temperature changes of fractions of a degree can be almost instantly detected. Strains set up in gun ports by rapidly changing temperature and sub-zero cold are continuously recorded for detection of possible weak points in design or construction. High speed movie cameras record movement of gun ports and can photograph projectiles in high velocity flight. Rate of fire of these weapons in rounds per minute can be determined with special instrumentation at any altitude from ground level to 50,000 ft. Personnel of this facility anticipated different bullet velocities at different simulated altitudes, but initial tests have shown no measurable difference. These tests were for a plane taking off at sea level and climbing to 50,000 ft. With long tests, temperature stabilization may affect bullet velocity.

Effect of extremely low temperatures on metals, fuels, lubricants and automotive parts can be determined in a section of this facility which is capable of producing a temperature of 110 F below zero.

Products Designed for Safety Win Awards

SEVEN NEW AND REDESIGNED HOUSEHOLD PRODUCTS were honored at the recent Lewis & Conger award dinner held upon completion of the annual home safety contest. Inaugurated to help prevent the almost 33,000 deaths caused by home accidents each year, the Lewis & Conger contests have interested almost 5,000 manufacturers in safe design.

Chief honors went to the Grand Home Appliance Co., for development of the Safe-Tee-Kee safety valve and key for use on gas ranges. The key, with a purpose similar to an automobile ignition key, throws the valve that stops flow of gas to all main burners. When the valve has been turned and the key removed to a safe place, children cannot light burners during play.

Honorable mention of six other items was made. A socket for light bulbs, that removes possibility of shock when bulb is removed, received a special citation with the honorable mention. Other products included: Powder that prevents rugs from slipping, multiple fuse with neon light to indicate when blown, metal tongs used to handle hot foods in the kitchen, smoking aid to prevent fires in bed and plastic drinking tumblers that will not break, chip or crack.

Machine Tool Builders Stress Control During Forum

MACHINE TOOL BUILDERS, users and component manufacturers chose "control" as the subject for their 12th annual Machine Tool Electrification Forum recently held in Buffalo, N. Y. The two-day session covered control techniques from details of design to influence on world economy. Fifteen prepared papers were delivered.

Machine tools themselves produce much of the real wealth of the world, and contribute heavily to all phases of production. With the United States making a large percentage of world production goods, our machines must be designed for increased productivity. Experience gained during this period can be transmitted abroad so war-ravaged countries can sooner reestablish their own production programs.

European countries now have different machine tool needs than the United States, according to E. Griffiths, consulting manufacturing engineer, Westinghouse Electric Corp. Lack of dollars prohibits importation of industrial products and these must be made for the first time. Machine tools will be needed for this, and to ease bottlenecks that have developed in existing production lines. They will also need to have machines for producing luxury items suitable for foreign trade. These must be produced for export in attempt to gain foreign credit. Fear of breakdown is limiting use of machine tools. If producers could be assured of replacement when existing machines wear out they could push production considerably. Efficient use of these machines and additions of auxiliary equipment could greatly aid European recovery.

Electrification of machine tools has occurred in the short span since the early 30's and K. T. Kuck, Vice President, Engineering, The Monarch Machine Tool Co., spoke on more recent advent of electronic control units. Efforts to achieve a truly variable-speed drive has accelerated electronic adaptation. Monarch saw that motor-generator sets could be replaced by tube controls and did much research toward reducing size of electronic units. Often electronic control equipment is many times larger than controlled motor. A 16 amp xenon-filled tube, developed at this time, was designed into a control system that satisfied space requirements without sacrificing speed range or regulation. This control, plus an electrical surface

speed indicator, reduces floor-to-floor operating time.

Less-skilled operators can successfully produce with machine tools equipped with proper instruments, as stated by R. J. Teetsell, instrument specialist, Westinghouse Electric Corp. Machine tool industry uses more instruments now than ever before, and instruments are becoming "eyes" for this industry. Power consumption and speed of units must be quickly and easily determined by operators for best results. Instruments must be placed convenient to operator position or they will be neglected. Recording instruments are doing much to indicate design of machines, and also show how effectively machine is used.

Many automatic lathes, according to E. P. Bullard, III, Vice President, in charge of engineering, the Bullard Co., were unable to use many advantages inherent in the engine lathe because automatic controls could not duplicate actions of an operator. Present controls, using electrical and hydraulic components, can duplicate three functions of human control: (1) Operation sequence control to determine function and order, (2) function stops and switches that determine time of operation, and (3) power to engage gears and clutches.

Human limits to machine design were introduced by J. J. Jaeger, electrical engineer, Pratt & Whitney Division, Niles Bement-Pond Co., during his discussion of a large, tracer-controlled milling (Kellering) machine. Since operator rides with the machine, with speeds of 250 in. per min, it was found necessary to carefully select motors. Operators were frightened by high acceleration rates and these had to be avoided.

Development of an automatic sharpening machine was described by Frank A. Glassow, application engineer, Barber-Colman Co. Coordination of mechanical, hydraulic and electrical controls required experimental analysis. A three-element magnetic oscillograph was used to simultaneously record data to determine instants of operation for five critical parts and the position and velocity of two other major parts. Incorrect operations, and reasons therefore, were easily discernible on oscillograms, and designers were able to correct these conditions. Some parts of the original design were found unnecessary and were omitted.

Over-enthusiasm for new ideas was listed by M. S. Curtiss, Assistant Director of Engineering, Warner & Swasey Co., as one fault of American design. High speeds have been overemphasized in many cases. Whenever there is a choice of the combination of speeds, feeds and depth of cut for a given rate of metal removal, Mr. Curtis would choose in the following order: (1) Deep cut, (2) heavy feed, and (3) high speed. High horsepower and superfinishing are two other instances of too much enthusiasm.

Metallic rectifiers, electronic rectifiers and motor-generator sets were compared by L. W. Herchenroeder, Westinghouse Electric Corp., as d-c power sources for machine tools. Each has advantages depending on final use of machine, load and overall economy. Installation costs of electronic and metallic units are about equal, and lower than those for motor-generators. Metallic rectifiers require less maintenance than the others. The m-g set introduces most vibration and requires most space at ordinary loads. In most cases the metallic rectifier is a logical choice for a general purpose d-c power supply. Electronic rectifiers are used at 230 v from $\frac{1}{2}$ to 5 kw and motor-generator sets are used at high loads.

General feeling of the Forum indicates need for greater productivity, more accurate control of machine tools and continued progress toward optimum use of electrification.

ASME HONORS A PAST PRESIDENT—In recognition of his services as president of the American Society of Mechanical Engineers in 1936, William L. Batt, president of SKF Industries Inc., was presented with a past president's pin by President E. G. Bailey of New York, N. Y. Presentation was made at Engineering Progress Show, May 11-16 at Philadelphia's Franklin Institute.

MEETINGS

August 18-20
SOCIETY OF AUTOMOTIVE ENGINEERS—West Coast Meeting, St. Francis Hotel, San Francisco, Cal.

August 24-27
AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS—Pacific General Meeting, Spokane, Wash.

September 7-9
SOCIETY OF AUTOMOTIVE ENGINEERS—Tractor and Diesel Engine Division Meeting. Hotel Schroeder, Milwaukee, Wis.

September 13-15
PENNSYLVANIA STATE COLLEGE—Conference on Research Administration. State College, Pa.

September 13-17
INSTRUMENT SOCIETY OF AMERICA—National Instrument Conference and Exhibit, Convention Hall, Phila.

September 20-21
AMERICAN SOCIETY OF MECHANICAL ENGINEERS—Aviation Division Meeting, Dayton, Ohio

September 20-24
ILLUMINATING ENGINEERING SOCIETY—Annual Meeting, Hotel Statler, Boston, Mass.

September 27-October 2
SOCIETY OF THE PLASTICS INDUSTRY—National Plastics Exposition. Grand Central Palace, New York, N. Y.

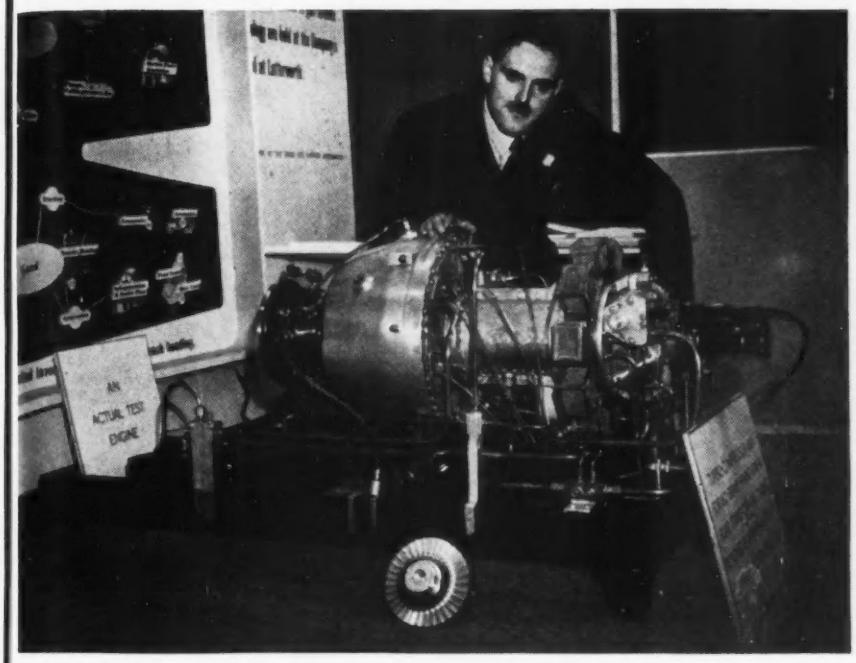
September 30-October 3
THE INSTITUTE OF RADIO ENGINEERS—West Coast Convention in conjunction with West Coast Electronic Manufacturers Convention. Biltmore Hotel, Los Angeles, Cal.

October 12-16
AMERICAN CHEMICAL SOCIETY—National Chemical Exposition and National Industrial Chemical Conference. The Coliseum, Chicago, Ill.

October 13-15
PORCELAIN ENAMEL INSTITUTE—Annual Forum. University of Illinois, Urbana, Ill.

October 22-25
METAL TREATING INSTITUTE—Annual Meeting. Adelphia Hotel, Philadelphia, Pa.

AMERICAN SOCIETY FOR METALS—Annual National Metal Congress and Exposition. Commercial Museum and Convention Hall, Phila., Pa.



AUTOMOTIVE GAS TURBINE turbo-compressor unit, made by Centrax Power Units Ltd., on show at British Industries Fair. Air intakes have box-like copper gauze filters. Power turbine would bolt to flanges at extreme left of unit; impeller in front.

British Progress Toward Motor Vehicle Gas-Turbine

Britain may yet be the first to put a gas-turbine powered motorcar on the road. Two recent disclosers gave some new clues as to how soon such an advance might be expected: (1) The Rover Company Ltd., of Solihull, Birmingham, has been testing a 100 hp gas-turbine that may be suitable for an automobile since February 3, 1947 and the unit has clocked more than 60 hours on the test bench. The engine may also have been tried out on the road, installed in a Rover chassis. (2) Centrax Power Units Ltd., of Acton, London, has developed a 160 hp gas-turbine engine that the company considers to be suitable for motor buses and heavy trucks.

The Centrax engine is undergoing preliminary tests. First prototype unit had been completed and was to start tests when the Government-owned company, Power Jets (Research & Development) Ltd., invited Centrax to display it on their stand at the British Industries Fair at Birmingham. Power tests started soon after the Fair closed.

Both the Rover and the Centrax engines follow similar lines. Both are basically scaled-down from gas-turbine aeroplane engines. Essence of their departure from aero engines is use of two independent turbines. One turbine drives the air compressor; the second, running on a separate shaft, gives power for the drive shaft, through reduction gears. Both turbines are driven by expanding gases from burning kerosene with highly-compressed air, either in a single combustion chamber (The Rover unit) or in a series of combustion chambers arranged circumferentially around the axis of the engine (The Centrax unit).

Details of the Rover engine have still not been fully disclosed, but *The Autocar*, weekly journal of the British motoring industry, this week revealed these: Turbine wheel is 5 in. in diameter; blades (around periphery) are formed in one piece with central disk; which, if true, represents an important development that could greatly cut production cost and reduce maintenance; turbine develops 100 hp at a designed speed of 55,000 rpm, although it has been run at speed of 70,000 rpm; high overall efficiency is assisted by the provision of a heat exchanger; dimensions are 36 in. long, 18 in. wide, 20 in. high.

Only the turbo-compressor unit of the Centrax gas-turbine engine was displayed at the BIF. The power turbine was said to be completed and the reduction gearbox well along. Neither of these units will be needed for the initial power tests.

Details of the Centrax unit: Air compressor has eight stages of axial-flow compression, followed by one stage of centrifugal compression with a single-sided impeller; total compression ratio is 5.8 to 1; gage pressure is 72 psi; compressor blades and casing are of aluminum alloy seven combustion chambers are arranged circumferentially around the axis of the engine; material is a nickel-chrome alloy; compressor-driving turbine is three-stage design; is expected to develop 330 bhp at full power and 40,000 rpm; compressor rotor is coupled directly to the turbine rotor shaft; exhaust gas from compressor-turbine drives independent single-stage power turbine, which has its own separate shaft; power turbine is expected to deliver 160 bhp when turning at 35,000 rpm; reduction gears (7 to 1 ratio) will reduce this to driving-shaft speed of 5,000 rpm. This power is calculated as being adequate to drive a bus or heavy truck at 105 mph.

Biggest problem in developing a small gas-turbine engine is scaling down precision-contour curved blades of compressor and turbine rotors. With reasonable care, these can be made to extremely close tolerances when blades are 3 in. long, as in aero-engines. But when blade size is reduced, it becomes a difficult problem. Success of Rover and Centrax designs depended on ability to produce blades this size with a dimensional tolerance of only $1\frac{1}{2}$ thousandths of an inch on the blade and $\frac{1}{2}$ on the root.

Introduction of the second, independent, power turbine is key to use of gas-turbine engines for road vehicles. The conventional aeroplane engine assembly has only a single power turbine which drives the compressor and whose excess power either turns a propeller shaft or is exhausted as a jet-stream. But the torque characteristics of such an assembly are not suitable for a unit which is to be used for motorcars or trucks.

Road vehicles need high torque at low speeds and a gas-turbine can deliver high torque at low speeds but the air compressor absorbs most of that high torque when operating at low rotor speeds. Consequently, a single-turbine unit won't do for road vehicles; cargo or passenger.

In a two-turbine system, the compressor turbine can operate independent of the vehicle's load and power requirements. And the power turbine, operating on a separate shaft, can develop its normal high torque even when the vehicle is moving at low speeds. At full charge, the torque may be almost twice that delivered at maximum speeds. The independent power turbine, therefore, operates with the same effect as a fluid drive—its speed varies with the load.

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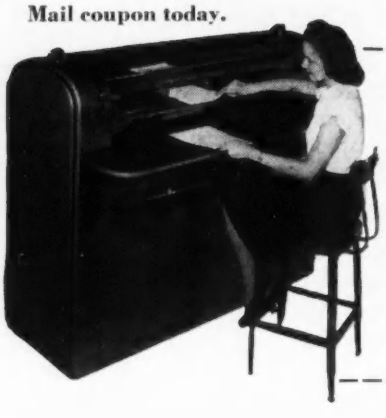

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Pressure Drop of Gases and Vapors Flowing Through Pipes

Formulas and chart for calculation of gas or vapor pressure drop losses in straight sections of inclined or horizontal pipes.

ARTHUR H. KORN
Chief Engineer, AirBorne Conveyors Corporation

BASIC EQUATIONS for fluid motion and pressure drops in pipes were given in a previous article, in the May 1947 number of PRODUCT ENGINEERING on page 85.

The general equation for pressure drop in gases and vapors flowing in an inclined pipe was found to be

$$e^{\frac{fS}{D}} = \left(\frac{p_2}{p_1}\right)^2 \cdot \left(\frac{p_1^2 + C^2m}{p_2^2 + C^2m}\right)^{m+1} \quad (1)$$

where
D = pipe dia, ft
e = Napierian base
f = friction factor
S = pipe length, ft
p_1 = starting unit fluid pressure, psi absolute
p_2 = terminal unit fluid pressure, psi absolute
C = constant, psi
m = constant

This equation has been derived assuming the pv product to be constant. For gases, the assumption requires that temperatures along line of flow be constant. For steam, however, it requires that temperature decrease slightly along line of flow.

Neither condition is exactly fulfilled in practice; but if the actual mean temperature or mean product, pv, is used to determine constant C^2 and m, the results will be substantially correct.

Constant C^2 and m are defined as

Gases	Steam

$$C^2 = \frac{16W^2RT}{\pi^2D^4g} = \frac{16W^2(pv)\text{mean}}{\pi^2D^4g} \quad (2)$$

$$m = \frac{fRT}{2D\sin\alpha} = \frac{f(pv)\text{mean}}{2D\sin\alpha} \quad (3)$$

where
W = rate of flow, lb per sec
R = gas constant, ft per deg F
T = Absolute temperature, $t + 460$, deg F
g = gravitational acceleration, ft per sec^2
α = inclination of pipe (sin α positive for up flow and negative for down flow
v = specific volume, ft^3 per lb
C = constant, lb per sq ft

For flow in horizontal pipes, sin α = 0 and $m = \infty$, so Eq. (1) becomes

$$f\frac{S}{D} = \left(\frac{p_1}{C}\right)^2 - \left(\frac{p_2}{C}\right)^2 - 4.6052 \log_{10}\frac{p_1}{p_2} \quad (4)$$

Calculating pressure drop from Eq (1) is time consuming.

A more convenient form may be developed if the equation is transformed so that fS/D is obtained as the difference between two values of identical functions.

Then

$$f\frac{S}{D} = J_1 - J_2 \quad (5)$$

where

$$0.4343\ J = (m+1)\log_{10}\left(\frac{p^2}{C^2m} + 1\right) - \log_{10}\frac{p^2}{C^2} \quad (6)$$

which applies when

$$\frac{p^2}{C^2m} + 1 > 0$$

and

$$f\frac{S}{D} = Y_2 - Y_1 \quad (7)$$

where

$$0.4343\ Y = (-m-1)\log_{10}\left(\frac{-p^2}{C^2m} - 1\right) + \log_{10}\frac{p^2}{C^2} \quad (8)$$

which applies when $-\frac{p^2}{C^2m} - 1 > 0$

These J and Y functions have been plotted in the accompanying diagram. For any specific flow condition, C, m and fS/D may be used to get the pressure drop $p_1 - p_2$.

Directions for use are given in the upper right hand corner of the chart.

The plots of Y and J functions show that for down flow, the functions become infinite when $p^2/C^2 = -m$. For this condition, the pressure drop is zero. Physically this means that the pressure drop due to fluid friction equals the gain caused by the increase of the height or weight of the fluid column.

The broken line marked "lowest Y's" indicates the lowest points of a valley or rather of a sharp pointed cleft in the Y-function. It represents a discontinuity in the function and occurs when $p^2/C^2 = -2m$. If a point Y_1 happens to fall on this line there are theoretically two solutions possible. Y_2 may lie on the very steep left hand or upper slope, which means a slight pressure drop, or it may lie on the gentler right hand or lower slope, which means a considerable increase in pressure in the direction of flow.

While this may be a rare occurence, in case it does happen there would be a rather unstable flow with the possibility of erratic changes from pressure drop to pressure gain or even an oscillation between the two conditions. The best thing to do then is to either increase or decrease pipe size with corresponding changes in velocities to avoid unstable flow.

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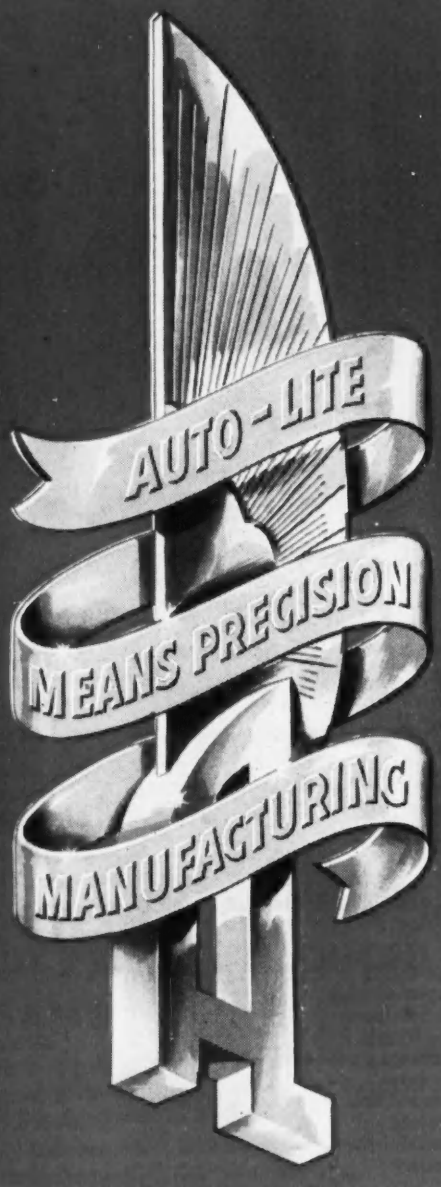

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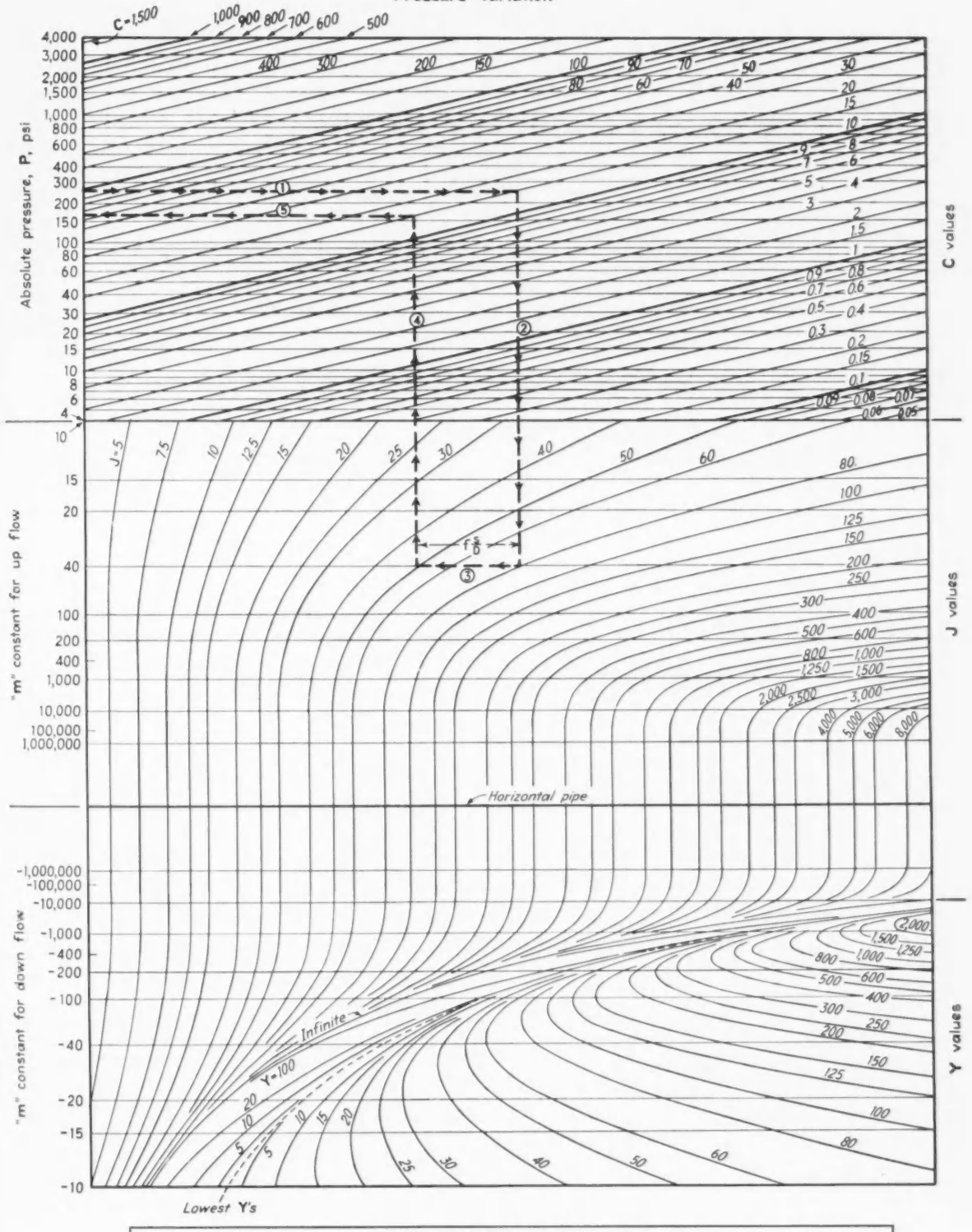
Pressure Drop of Gases and Vapors (continued)

Flow of Gases and Vapors in Horizontal or Inclined Pipes

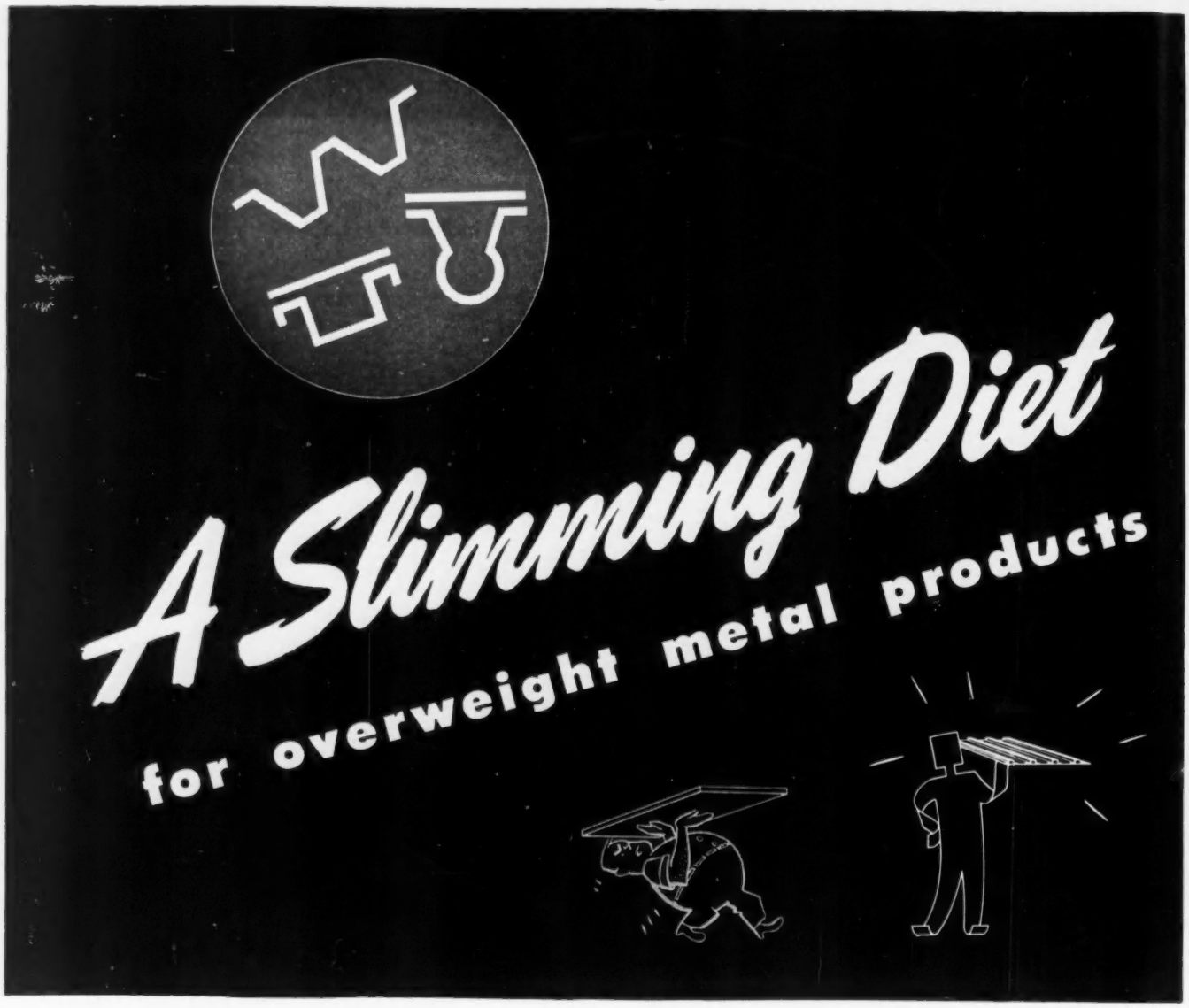
Pressure Variation



Procedure for Getting Pressure Drops

1. Using starting pressure P_1 (absolute), find intersection with C
2. Find intersection with m; locate J_1
3. Deduct computed value for $f\frac{s}{D}$ from J_1 to get J_2^*; locate point on chart
4. Find intersection with C
5. Read terminal pressure P_2
6. $P_1 - P_2$ = pressure drop in pipe

* *NOTE — If trace leads into Y area, add $f\frac{s}{D}$ to Y_1 to get Y_2. Other operations remain the same*



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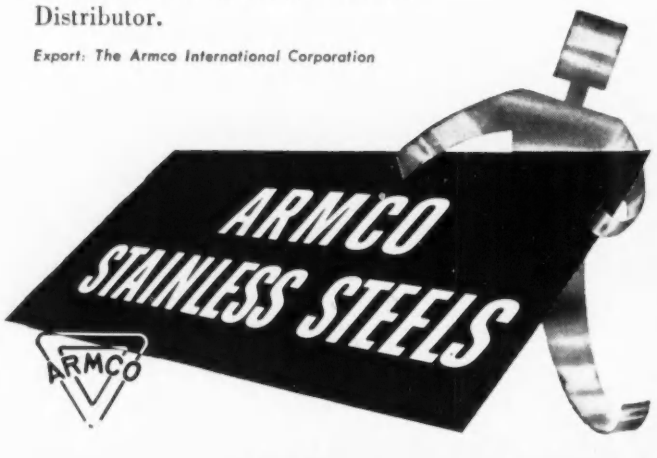

NEW MATERIALS AND PARTS

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Roller Bearings

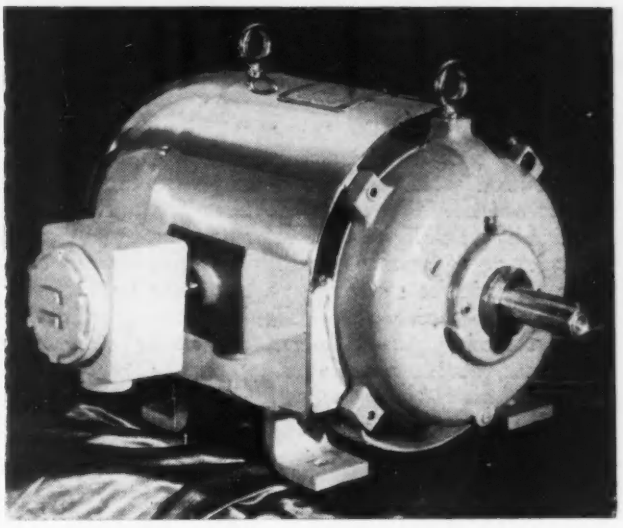
Rollway Bearing Co., Inc., Syracuse, N. Y.

Tru-Rol roller bearings have one-piece steel retainers with deep, broad, double flanged or lipped pockets for alignment of rollers. Outer race has deep ring grooves into which fit heavy snap rings that hold rollers and retainer. Inner race is separate and can be used whenever called for in specific designs. Bores cover range from 25 to 140 mm and boundary dimensions are identical with those of standard SAE bearings.

Solenoid Valves

Airmatic Valve Inc., Cleveland, Ohio

Requiring no pilot or other medium for operation, DS-2 solenoid valve provides an effective orifice area equal to that of the line. Internal parts are corrosion resistant and no packing is used in conjunction with a removable resilient rubber seat. Valves can be used in ¼ to 3 in. standard pipe lines carrying oil, water, steam, air or freon. Increased utility has been gained by making the solenoid operable from either a-c or d-c power sources.



Chemical Motors

The Reliance Electric & Engineering Co., Cleveland 10, Ohio

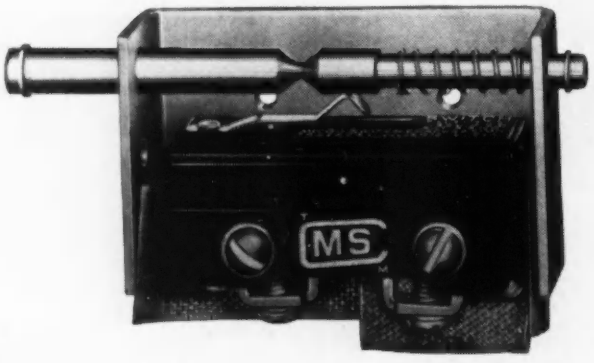
Designed for use in hazardous conditions, these squirrel cage fan cooled a-c motors are both corrosion resisting and explosion proof. Outer cover, fan enclosure and lead outlet are Monel metal, fan is cast bronze, and other critical parts are made of specialized materials. Bronze shaft collars provide bearing protection and multi-wire cable, rubber hose and special packing glands meet Bureau of Mines specifications. Motors are available with ratings of ⅓ hp at 680 rpm to 20 hp at 3600 rpm. Operation can be from two or three-phase, 25 or 60 cycle. 110, 208, 220, 440 or 550 v power sources.

Coolant Pumps

Allis-Chalmers Mfg. Co., Milwaukee 1, Wis.

Types KF and KW seal-less coolant pumps are designed for general circulation duty and machine tool applications. Units are vertical submerged and side-wall mounted, respectively, with low-head, single-stage characteristics suitable for close-coupling to motor. Type

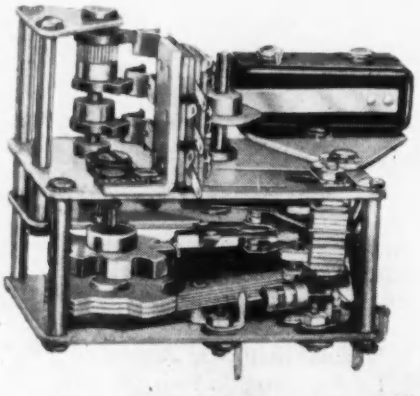
KF is double-suction, open impeller for vertical operation with continuous flooded suction. Liquids with solids, chips or suspended abrasive particles are handled by this model. Type KW handles similarly laden liquids and has two different lengths of adapter to suit coolant reservoir depths. Pumps are available in $\frac{1}{4}$ to 1 hp sizes, rated at 1,725 to 3,450 rpm under 10 to 70 ft heads.



Inter-Lock Door Switch

Micro Switch, Freeport, Ill.

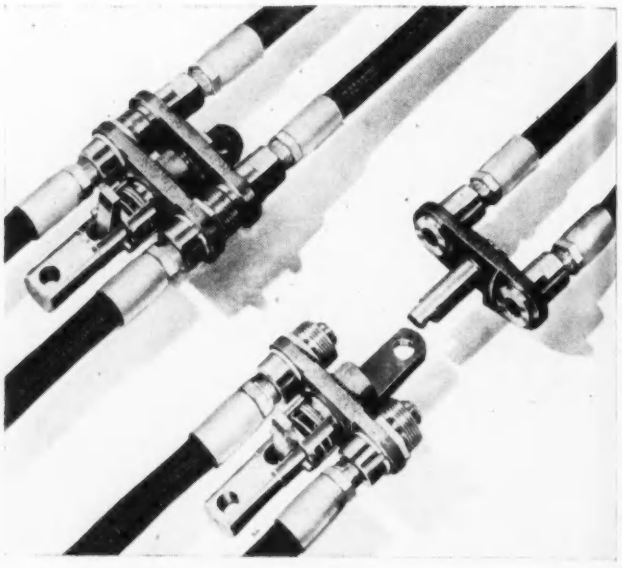
Designed for use in electrical equipment cabinets, Type 1AC1 switch automatically cuts off power circuit when door is opened. Circuit can be temporarily closed for checking by manually pushing actuator rod without hazard of forgetting to reposition switch for open circuit. Provision is made for mounting on two faces and actuator rod has deep threaded hole for insertion of adjustable length actuating pin or button. Switching element is single-pole, double-throw with 10 amp, 125v; 5 amp, 250v; or 3 amp. 460v a-c ratings.



Constant Speed D-C Motor

Amglo Corp., 4234 Lincoln Ave., Chicago 18, Ill.

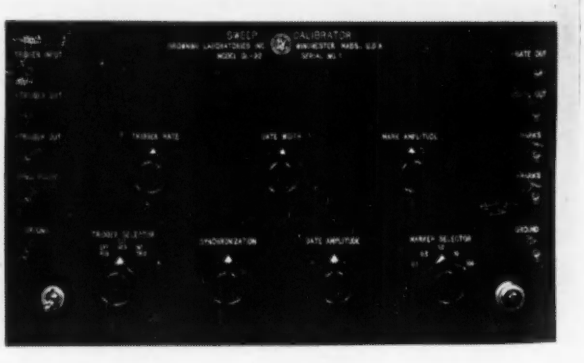
Redesigned for compactness and light weight constant speed d-c motor measures $2\frac{1}{2}$ x $3\frac{1}{2}$ x $1\frac{5}{8}$ in. and weighs only 10 ounces. Unit operates on magnetic drive principle of a vibrating reed that provides clock-like speed control. Available for use on 3 to 110 v lines or batteries, motor has rotor shaft speed of 900 rpm. Built-in aluminum reduction gears, special cams and switching can be furnished to meet specific application requirements.



Double Hydraulic Coupling

Aeroquip Corp., Jackson, Mich.

Twin Breakaway couplings provide positive, quick connection of either pressure or return hydraulic accessory lines. Self-sealing fittings are held in coupled position by the mechanical latch that automatically trips when an external tug is applied to the connecting lines or when a 60 lb pull is exerted on the trigger. Flush valve faces permit easy cleaning and pressure drop through the units is negligible. Couplings will carry pressures up to 1,000 psi. Both assemblies are made to fit standard $\frac{1}{2}$ in. pipe threads.



Sweep Calibrator

Browning Laboratories, Inc., Winchester, Mass.

Model GL-22 calibrator is a pulsed timing marker oscillator designed for use with standard oscilloscopes and synchroscopes. Accurate measurements of time intervals on either triggered or recurrent sweeps can be made. Variable amplitude markers of either polarity are provided with sufficient amplitude for use as intensity markers or directly on cathode ray tube plates as deflection markers. Markers available are 0.1, 0.5, 1.0, 10, 100 microseconds. A positive or negative variable width gate pulse output is provided for test purposes. The duration of this pulse corresponds to the duration of the marker group. Operation of the calibrator may be by use of external synchronizing triggers or from its own trigger generator with

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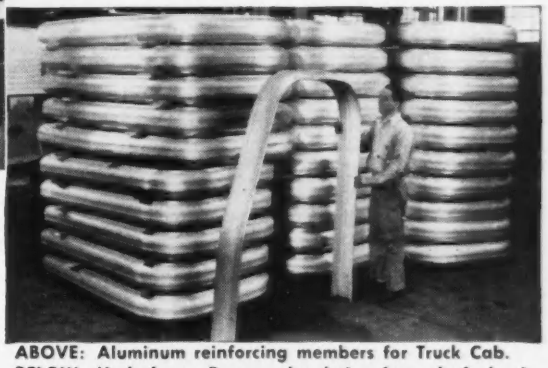
LEFT: Wheelhouse reinforcing members for Bus made of aluminum extrusions.



ABOVE: Aluminum reinforcing members for Truck Cab.
BELOW: Underframe Bus member being formed of aluminum extrusions.

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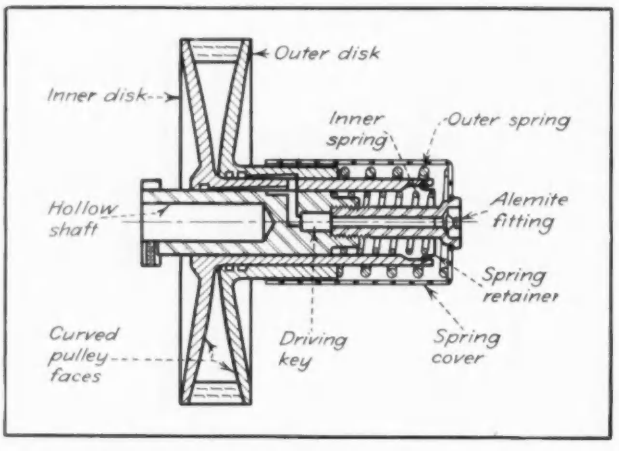
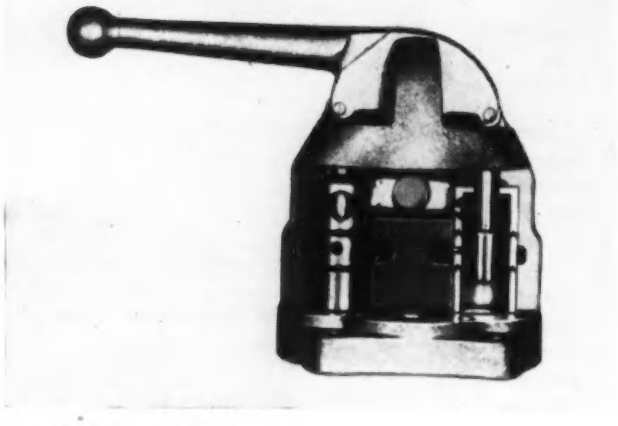
output triggers of both polarities available at front panel connections. Dimensions are 14 in. long, 7 in. wide and 7 in. high.



Variable-Speed Pulleys

Lovejoy Flexible Coupling Co., 5001 W. Lake St., Chicago 44, Ill.

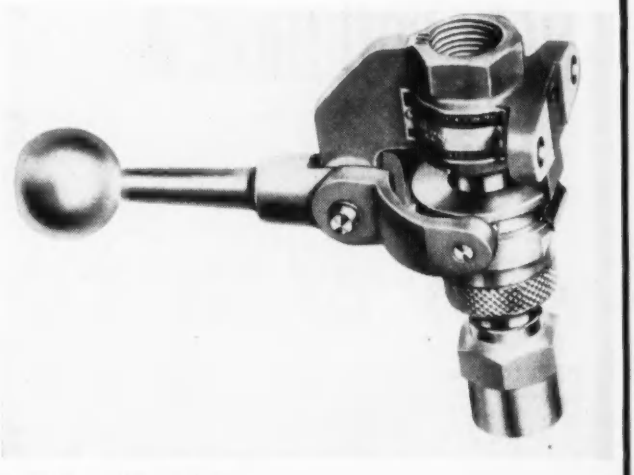
Both guide flanges of standard and wide V-belt series pulleys move on a single sheave to insure proper alignment at all times. Curved faces on spring-retained flanges provide positive belt contact. Units fit directly on motor shaft and are locked with set screw. Standard Series pulleys have speed ratio of 2:75 to 1 for fractional horsepower drives while Wide Belt Series have infinitely variable adjustments in 3 to 1 range for 1 to 8 hp drives. All motor ratings are at 1,750 revolutions per minute.



Air Control Valve

Lindberg Eng'g Co., Air and Hydraulics Div., Chicago 12, Ill.

Model HV balanced piston hand-operated air control valves permit simple cylinder control. When in neutral position, three-position lever can be adjusted to make actuated piston stop at any point along its stroke. Body, handle and base plate are cast aluminum alloy. Stainless steel pistons ride in bronze sleeves having synthetic rubber V-packings and O-ring seals. Valve is rated at 20 psi working and 175 psi maximum pressure. Assembly weighs approximately 3 lb, has either $\frac{3}{8}$ or $\frac{1}{2}$ in. pressure ports and $\frac{1}{2}$ in. exhaust ports.



3-Way Air Valve

C. B. Hunt & Son, Inc., Salem, Ohio

A flat spring indexes and holds the handle of the 1291-N3 air valve in "on", "off", "hold" or "neutral" position. Designed for use with single acting air cylinders, valve is particularly suited to hoists and other applications where quick load positioning is required. Head and handle are forged bronze while body and adopter are stainless steel. Unit is available with $\frac{3}{8}$ or $\frac{1}{2}$ in. pipe threads and pressures up to 250 psi can be handled. Length between connections is 5 inches.

Small Multi-Wire Connector

Winchester Electronics Co., 6 E. 46th St., New York 17, N. Y.

The Monobloc construction of the type PM6P six-contact connector reduces flashover and creepage between terminals. Tests with a 6,000 v d-c potential existing between pins have not produced corona. The molded melamine housing is polorizing and safety is provided by the "make first, break last" center contact that can be used as a grounding wire. The spring lock and hood prevent accidental disconnection and contamination. Cap at right of illustration acts as a protective cover when unit is disassembled. Unit is $1\frac{1}{4}$ in. in diameter and is designed for panel mounting on industrial, communications and aircraft equipment.

Embossed Aluminum Sheet

Reynolds Metals Co., 2500 S. 3rd St., Louisville, Ky.

Sheet aluminum embossed in a variety of patterns provides an attractive finish and greater stiffness to products

An Advance Lacquer Did the Job

● Foxworthy Motors, Inc., Indianapolis, authorized rebuilders of automotive engines, required a fast-drying, attractive finish with high adhesive qualities that could be applied to engines immediately after testing. Foxworthy called in technicians of the Advance Paint Company to solve the problem.

Advance formulated for Foxworthy a lacquer that adheres to metal surfaces which may be covered with residual grease, oil, and water. Applied to warm engines as soon as testing is completed, this Advance lacquer is air dried, permitting handling within five minutes. It is applied with a standard spray gun by an operator with no special training.

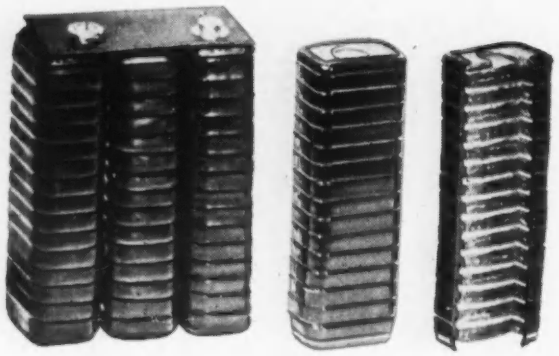
Foxworthy Motors has used this Advance lacquer for a year with highly satisfactory results. Nearly 12,000 passenger car and truck engines have received attractive finishes in a simple operation.

The Advance Paint Company can solve your metal-finishing problem by creating a finish which fits your specific needs. Write for the recommendations of Advance technicians.

Manufacturers of Industrial Finishes

Advance PAINT COMPANY
INDIANAPOLIS, INDIANA

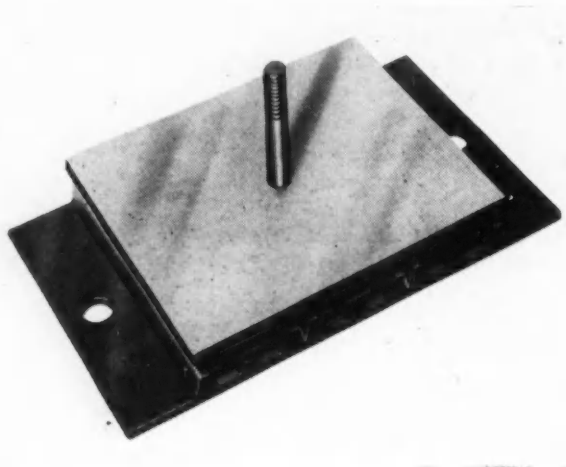
commonly made of the standard flat sheet. Squares, diamonds, stucco and simulated grained leather, as well as crosswise and lengthwise ribs comprise the patterns now available. Raised positions effectively hide scratches and other evidences of rough usage or wear. Material can be supplied in flat sheets of thicknesses ranging from 0.01 to 0.04 in. and in widths from 12 to 48 in. Coiled sheet is available in widths up to 36 inches.



Miniature Dry Cell Battery

Winchester Repeating Arms Co., Div., Olin Industries, Inc. New Haven, Conn.

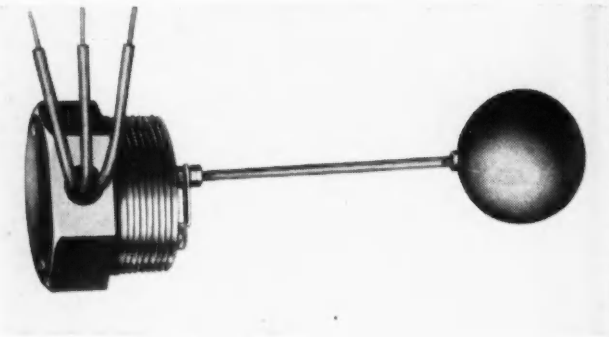
Assembled from interlocking wafer shaped, $1\frac{1}{2}$ v plastic cells, minature dry cells have 20 percent longer life than existing models. The interlocking feature reduces the number of soldered connections in the $67\frac{1}{2}$ v, three section unit illustrated by about 91 percent. Overall dimensions of this assembly are $2\frac{5}{8}$ in. wide, $3\frac{1}{2}$ in. high, $1\frac{1}{4}$ in. deep. These light weight batteries are used extensively in portable radios and hearing aids. Standard cells are rectangular but they can be produced in a variety of shapes to fit specific applications.



Vibration Mounts

Finn & Co., 2850 *8th Ave., New York* 30, *N. Y.*

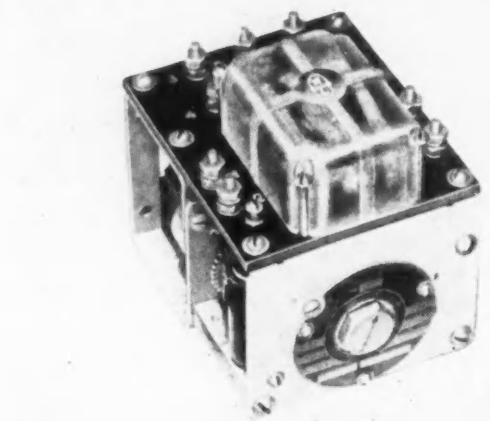
Finnflex Vibration Dampeners are designed around the principle of "rubber-in-shear" that prevents overloading of the synthetic rubber inserts. Design involves no-rubber-to-metal bonds that are subject to breakage during use. Type CM-H mounts are designed for horizontal or rotary vibration use under grinders, lathes, pumps and compressors; type CM-V mounts are for top-heavy machines like punch presses and shears where vertical vibration causes recoil and rocking. Easily installed, mounts are sturdy, durable and inherently stable.



Magnetic Proximity Switch

Magneswitch, Inc., 4219 S. Western Blvd., Chicago 9, Ill.

Actuated by a permanent magnet, snap-action switch has many uses for automatic control service. In application shown, there is no mechanical linkage with float part of liquid level control mechanism. As float oscillates, magnet snaps toward magnetic armature and operates switch. Differential adjustment of leverage exerted by float can be made. Heavy loads can be handled without use of relays or auxiliary devices. Measuring 2 1/32 in. in diameter, switch operates on 115v a-c power with 10 amp non-inductive load. Motors up to $\frac{1}{4}$ hp can be handled.



Time Delay Relay

Ward Leonard Electric Co., Mount Vernon, N. Y.

Bulletin 362 motor-driven a-c time delay relay is self-recycling and easily adjustable over timing range to 6 minutes maximum. Unit is designed for use in processing, machine tool, signal, sound and other equipment where remote, automatic or sequenced operation is required. With proper use of jumpers between composite connections, "delayed make" with maintained pilot circuit or "instantaneous make" and "delayed break" with monetary contact pilot circuit can be obtained. Major com-

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Photo courtesy of General Electric Company

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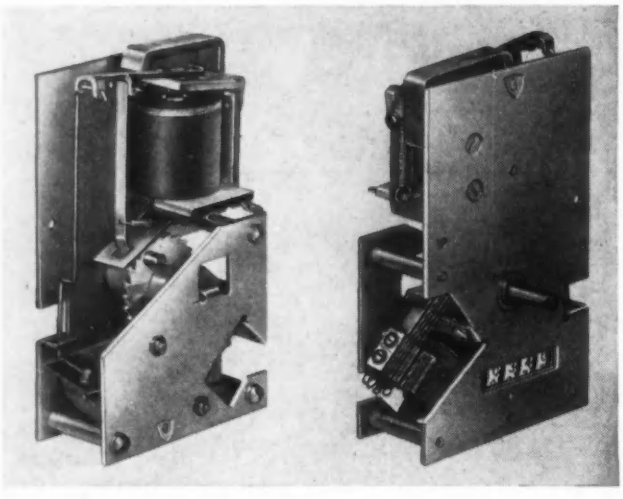
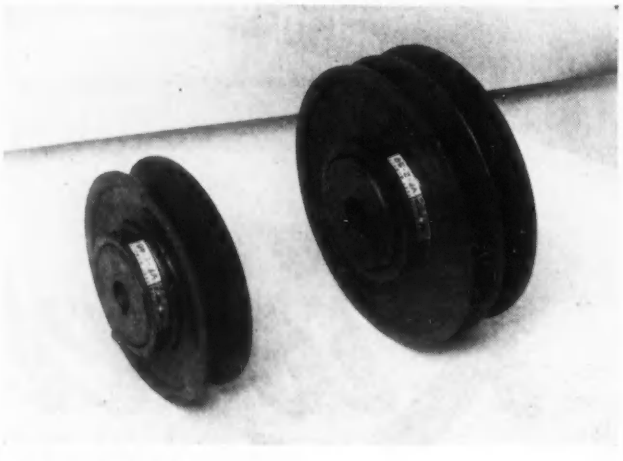
ponents of the relay consist of a small synchronous motor, a differential gear system, a built-in brake assembly and an auxiliary relay.



Magnet-Driven Counter

Guardian Electric Mfg. Co., 1637 W. Walnut St., Chicago 12, Ill.

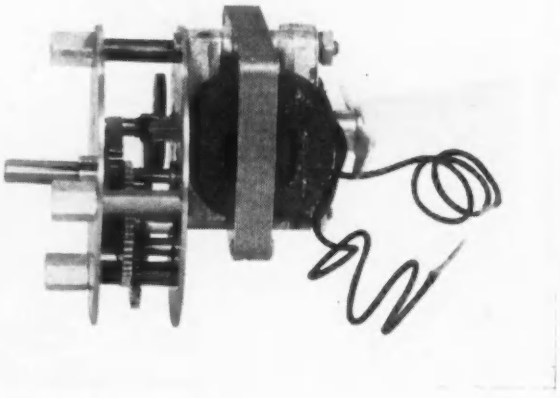
Pulse-actuated magnet driven counter is used to register remote musical record selections in a centrally wired music station. The deposit of a nickel, dime or quarter transmits one, two or five pulses that energize magnet at top of illustration. Movement of armature assembly causes wire linkage to move counter one digit and lever to step cam one notch. As cam leaves "off" position, blade switch "makes" in two positions energizing indicating light and buzzer. Unit can be utilized for a variety of similar counting uses in varied fields.



Adjustable Sheaves

Worthington Pump and Machinery Corp., Harrison, N. J.

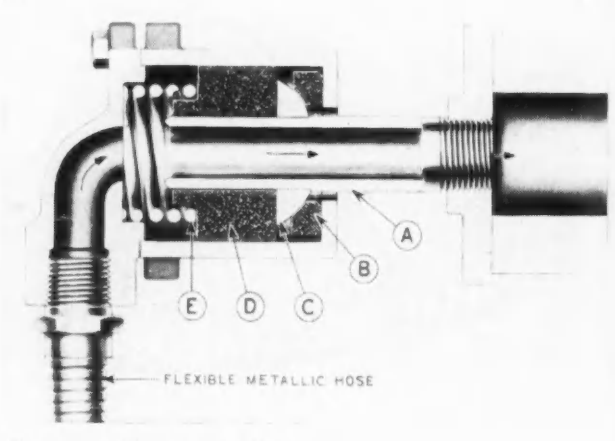
Adjustable to accommodate most common types of V-belt, fourteen sizes of Fhp sheave—seven single groove and seven double groove—are designed for maximum uniformity of pitch diameter and flange stability. Stationary flange has one or two hubs externally threaded to fit removable flange or flanges. Milled flats 180 deg apart receive positioning set screws for locking the assemblies.



Versatile Gear Train

Gleason-Avery, Inc., Auburn, N. Y.

Gear train for use with small synchronous and non-synchronous motors can produce speeds in either direction from 400 to 1 rpm on final shaft. Compact and quiet, unit is well suited for large timers, displays, vending and other machines where maximum torque is required. Gears are cut to close tolerances and ride between round, securely mounted plates. Dust proof, fan cooled motors are available in all normal voltages and frequencies with wide range of synchronous speeds. Overall dimensions of low speed unit with open or enclosed gear train are $3\frac{1}{4}$ x $3\frac{1}{4}$ x $3\frac{1}{4}$ inches.



Rotary Pressure Joints

Johnson Corp., Three Rivers, Mich.

Self-supporting and self-lubricating, Type-S rotary pressure joints are applicable to processing equipment where considerable lateral movement is encountered. Nipple "A" is attached to roll or cylinder. Carbon graphite seal ring "B" fits against rotating shoulder "C" on nipple and entire weight of joint is supported by carbon graphite guide "D". Spring "E" effects initial sealing although, in operation, line pressure is actual sealing force. Four sizes of joint are available—$\frac{1}{2}$, $\frac{3}{4}$, 1 and $1\frac{1}{4}$ inches.

Light-Weight Ball Bearings

Federal Bearings Co., Inc., Poughkeepsie, N. Y.

Savings in space and weight without sacrifice of load carrying capacity are design features of Series XLS ball

Why Designers Select CRANE . . .
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Flow control equipment is so important to successful design that it pays to be sure. Wherever piping is used, you can protect the operating efficiency of your design by specifying Crane. You can get valves, fittings, piping accessories and pipe for every need . . . all from this one complete source of quality equipment. One catalog gives you the world's most complete selection and specifications of brass, iron, steel or alloys.

When Crane takes the responsibility for supplying all your piping equipment, it means simplified buying, easier storekeeping . . . and piping assembly work is more likely to go smoother and faster.

Buyers, too, know that Crane materials give your product added value. They know that Crane Quality is high quality . . . unsurpassed for more than ninety years.

Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.

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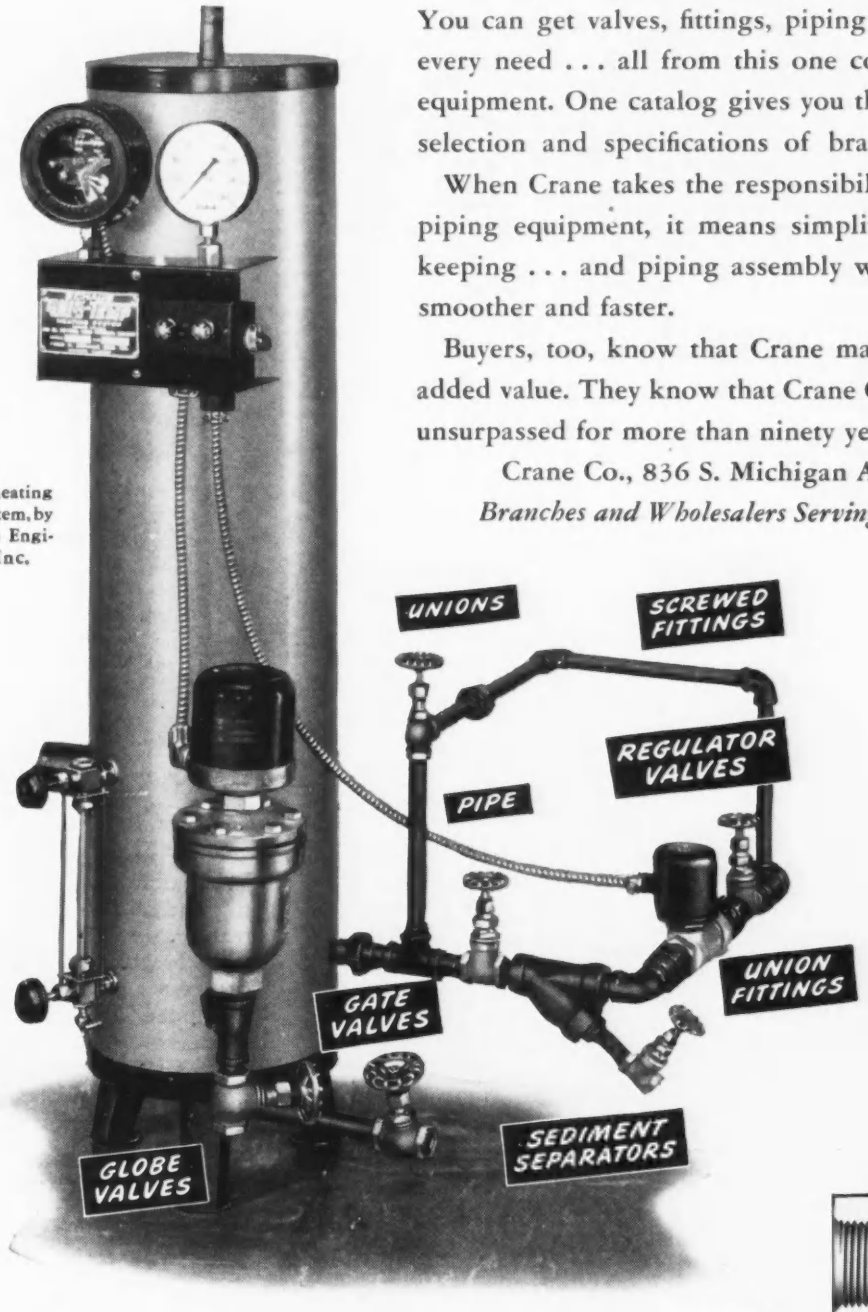
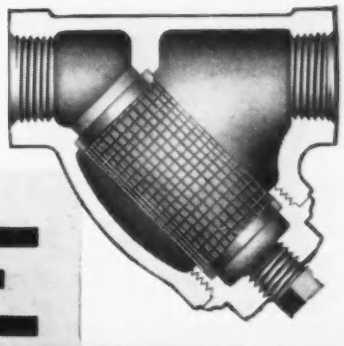


"Quik-Temp" heating and drainage system, by Fred H. Schaub Engineering Co., Inc.

FOR SEDIMENT SEPARATORS *to protect the seats of automatic valves and other flow control apparatus, see pages 422 and 423 of your Crane Catalog. Choose from vertical screen and Y-pattern types, iron and steel, in sizes up to 12-in., for working pressures up to 600 pounds steam. Supplied with screen of mesh and material best suited for specific needs. Crane high-efficiency design allows easy clean-out and replacement of screen.*



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VALVES • FITTINGS
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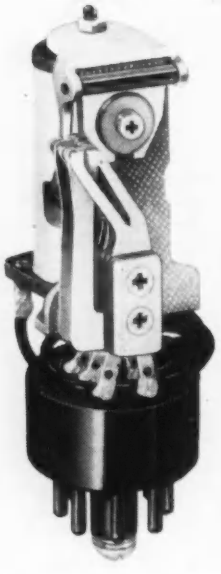
AND HEATING

CRANE

FOR EVERY PIPING SYSTEM

bearings. Uninterrupted deep-groove races will take thrust loads in either direction as well as radial loads. Produced with bores ranging from 1⅜ to 10 in., cross sectional area through any pair of races varies from 68 percent for small sizes to 33⅓ percent for large sizes of corresponding size metric bearing. Applications include clutches, thin-walled housings and other locations where space and weight are prime factors.



High Current Relay

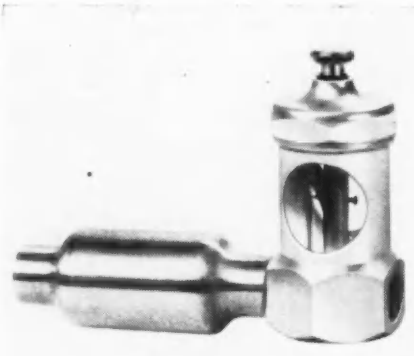
C. P. Clare & Co., 4719 W. Sunnyside Ave., Chicago 30, Ill.

Ease of installation and replacement has been attained through the application of a standard octal base to Type J d-c relay assembly. Installed height is 2 15/16 in. above panel. Bifurcated "twin" contacts are rated at 4 amp, 150 w a-c non-inductive and spring pile-ups can be made using maximum size 20-point plug up to 10-pole, single-throw or 6-pole double throw. Coils of resistance from 1 to 21,000 ohms are available for use with d-c voltages up to 220 volts. Magnetic structure incorporates ample iron and large armature bearing area for positive high speed operation.

Ruled Sketch Paper

Brooklyn 17, N. Y.

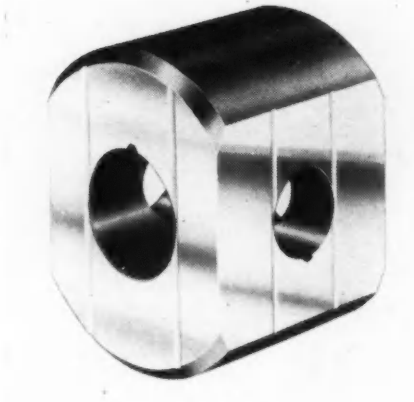
The Ogilvie Press, 691 Fulton St., Made from 100 percent rag material tracing bond, Bondtex 150 sketch paper has cross section ruling that will not reproduce. Rules are ¼ in. apart both horizontally and vertically and afford handy reference lines when making sketches to propoer proportions. Lines do not appear on blueprint, black and white or Ozalid reproductions. Cut to 8½ x 11 in. size, sheets are available with or without holes for three-ring binder and standard data headings. Other standard forms come with 4 x 4, 5 x 5, 8 x 8 and 10 x 10 spaces per inch or isometric.



Air Filter-Lubricator

Jarett Compressor & Equipment, Inc., 275 Central Ave., Newark 4, N. J.

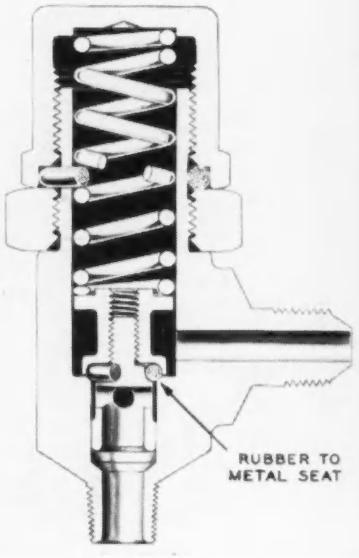
Model 605 Lubri-Filter protects air-driven equipment against "dry-running" breakdowns and filters air supply. Chamber at left of illustration contains a sintered metal cartridge that provides "three dimensional" filtration at high rates of air flow. As clean air passes through base of lubricator chamber, metered oil is atomized and carried into protected equipment. The ½oz oil supply maintains lubrication for period as long as standard lubricators having larger oil capacities.



Universal Joints

Curtis Universal Joint Co., Inc., Springfield, Mass.

Heat generation between bearing surfaces in universal joints has been reduced through redesign of center block faces. The four bearing surfaces have been divided into a total of sixteen smaller areas by the use of two grooves in each face. Wear distribution becomes more even, lubrication is more effective and frictional heat is dissipated more uniformly and rapidly than in standard assemblies. Grooved center blocks are being incorporated in joints having from 1¼ to 4 in. outside diameters.



Relief Valves

Parker Appliance Co., 17325 Euclid Ave., Cleveland 12, Ohio

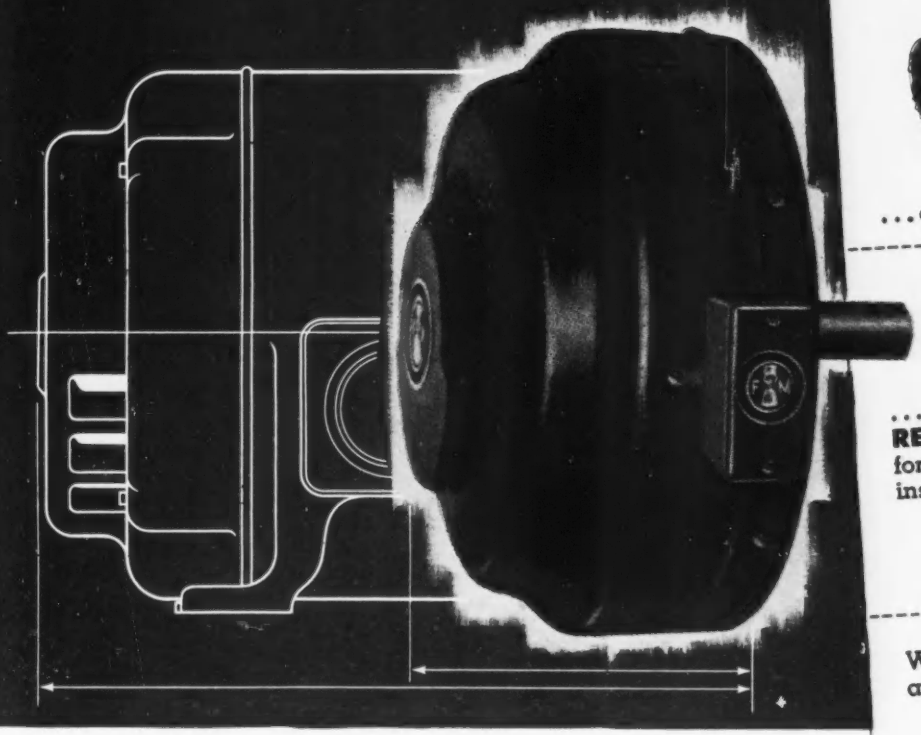
Rapid unloading and silent operation characterize these hydraulic and pneumatic relief valves. Adjustment is made by positioning threaded cap that determines pressure of internal spring on guided shut-off piston. Valves for hydraulic applications have metal-to-metal seats. Bodies and caps are aluminum or brass, pistons and springs are stainless steel or brass. Available in 0-15, 10-50, 40-125, 115-230 and 235-450 psi pressure ranges, valves cover six basic sizes from ¼ to ¾ inch. Larger sizes for higher pressures are also obtainable on special order.

Hydraulic Control Unit

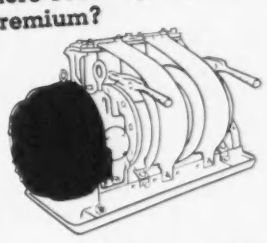
Electrol, Inc., Kingston, N. Y.

Powerpak, a control center for hydraulic systems, is designed to meet a wide variety of applications in the machines of industry, agriculture and transportation. Unit is capable of exerting precision-controlled forces by finger-tip actuation to a maximum op-

Where can You use a lighter, shorter electric motor?



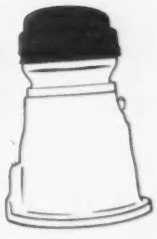
Where Floor Space is at a Premium?



. . . as with this **SLUSHER**

Where Headroom Counts?

. . . on **GEAR REDUCERS,** for instance



Where Weight and Space are Important?

. . . as on this **TILTING ARBOR SAW**

Where Appearance Helps to Sell?

. . . on **FLOOR POLISHING MACHINES** . . . and hundreds of other applications

FAIRBANKS-MORSE AXIAL AIR-GAP* MOTORS offer new possibilities in the application of electric power! These motors are radically advanced in design — over 30% lighter, 50% smaller than other motors of equal horsepower . . . yet they are 40-degree, standard wound squirrel-cage motors, with a range of application that is broader and more flexible than motors of conventional design. Their size, weight and design are new — their performance meets long-established Fairbanks-Morse high standards. Bulletin 2760 has full details . . . write Fairbanks, Morse & Co., Chicago 5, Ill.

**Air-Gap dimension is measured parallel to the axis of the shaft. Horizontal and vertical mountings; also, pivot base mountings. Polyphase squirrel cage and capacitor start, single phase types.*

when it comes to Electric Motors . . .

FAIRBANKS-MORSE

A name worth remembering

DIESEL LOCOMOTIVES • DIESEL ENGINES • STOKERS • SCALES • MOTORS • GENERATORS
PUMPS • RAILROAD MOTOR CARS and STANDPIPES • FARM EQUIPMENT • MAGNETOS

erating pressure of 1,500 psi. The compact design consists of a hand pump, reservoir, two selector valves, relief and check valves. Body assembly stands 4½ in. high on a base measuring 3½ x 4 inches. Reservoir capacity can be varied to meet individual requirements, and power-driven pump lines can be attached at two plugged openings. The ⅛ in. N. P. T. ports and handle can be modified to suit individual needs.

Differential Gage

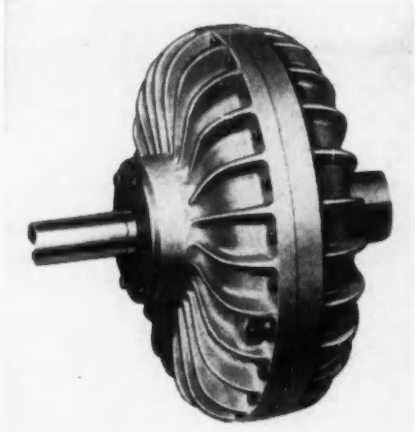
Kollsman Instrument Div., Square D Co., 80-08 45th Ave., Elmhurst, N. Y.

High sensitivity and wide range of indication are combined in this differential pressure gage. Particularly applicable to laboratory and flight testing of jet turbine engines, instrument has range of from 0 to 300 in. of water and working pressures not exceeding 60 psi. Scale can be read accurately to within 1/10 in. of water throughout entire range. Gage is calibrated so that large pointer makes one revolution for each 10 in. of water and small pointer indicates number of revolutions of large pointer.

Wire Terminals

Aircraft Marine Products, Inc. 1585 N. 4th Street, Harrisburg, Pa.

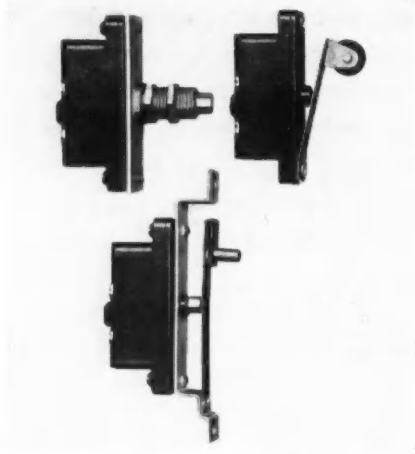
Shur-Plug terminal for size 16-14 wire permit easy installation or replacement of connections on leads in electrical appliances, automotive equipment, personal aircraft and machinery circuits. Solderless application is accomplished by crimping with special hand tool, or by foot or power press. Connection has high electrical conductivity and corrosion resistance. Terminals are for stranded wire and designed to make perfect plug-in connections with standard female fittings.



Hydraulic Coupling

CraneVeyor Corp., 1240 S. Boyle Ave., Los Angeles, Calif.

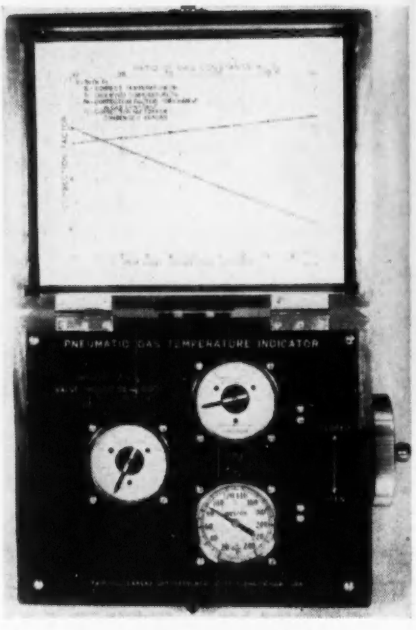
Fluidrive is a completely self-contained hydraulic coupling with simple impeller element and runner unit mounted on integrally-fitted ball bearings. Straight radial vanes make possible operation in either direction with equal efficiency. Low inertia of impeller and runner facilities quick stops and reversing duty. Unit is statically and dynamically balanced, requires a minimum of mounting space and is simple to install. Housing is made of precision-molded aluminum alloy castings, with all mating surfaces accurately machined. Couplings are available in two sizes: 8.5 in. dia with capacity up to 5 hp and 9.5 in. dia with capacity up to 7½ horsepower.



Snap Switch Operators

Square D Co., Industrial Controller Div. 4041 N. Richards St. Milwaukee 12, Wis.

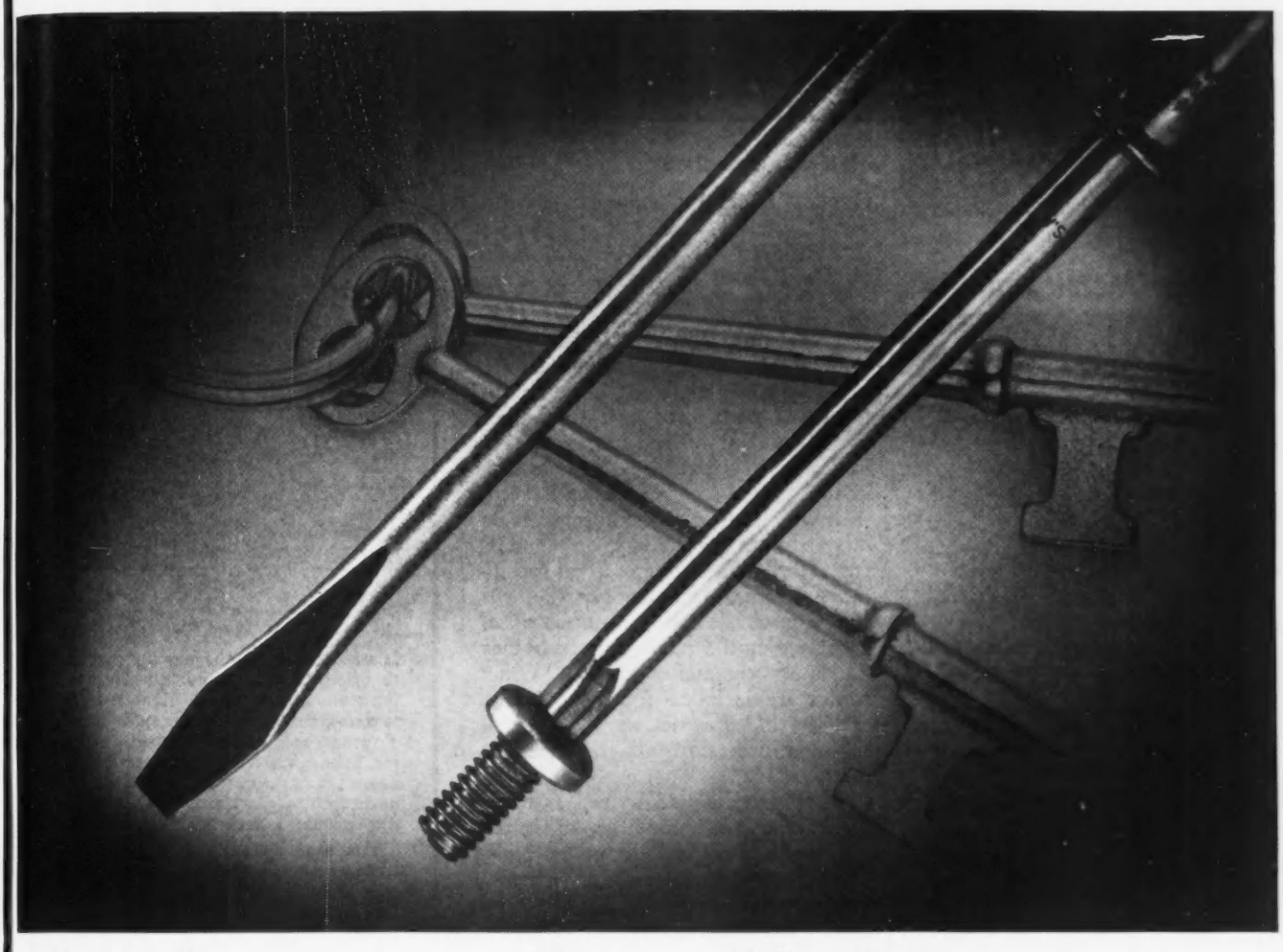
Three types of operator provide increased utility for the snap action switches to which they are attached. Plunger type, top left, containing an overtravel spring under the button is for panel mounting. Adjustment in relation to the distance from the actuating cam is made through positioning of the two nuts. Roller-leaf unit, upper right, carries a nonmetallic roller on the beryllium copper arm. Mounting screws go through the spun rivets in the case extensions. Door-type switch is designed to function as an electrical interlock on cabinets and related installations. Contacts in the switch body are rated at 600v pilot duty, a-c or d-c power supply.



Gas Temperature Indicator

Fairchild Camera and Instrument Corp., 88-06 Van Wyck Blvd. Jamaica 1, N. Y.

Temperature up to 5,000 F can be measured with the Unit 263 laboratory gas temperature indicator. Insertion of a probe into the gas stream and operation of a single control valve on the instrument case are the only operations required. Accuracies of one percent up to 2,000 F and two percent in the 2,000 to 5,000 F range are guaranteed. The basic pneumatic gas temperature system used is a form of gas thermometer and utilizes the density of the gas being measured as a direct indication of temperature. Probes of suitable metals are furnished for temperatures to 2,300 F; water-cooled probes with iridium orifices are furnished for temperatures to 5,000 F. Probe diameter, length and shape are made to customer specifications. Indicator is especially suited for use with gas turbines, turbo jets, ram jets, rockets and general industrial laboratory use.



Here's How CLUTCH HEAD *Opens The Door To Simplified Field Service*

PERFORMANCE ON THE JOB measures the value of your product to the user . . . it also measures your reputation and your sales volume of the future. Hence, these two keys to simplified field service . . . *provided only by* CLUTCH HEAD . . . are vitally important to the quality and continuity of your job's performance.

KEY NO. 1 is the logical basic design of the CLUTCH HEAD recess for operation with a common screwdriver. Note that any flat blade will do and that it need only be reasonably accurate *in width* . . . that the roominess of the recess makes thickness of the blade a secondary consideration.

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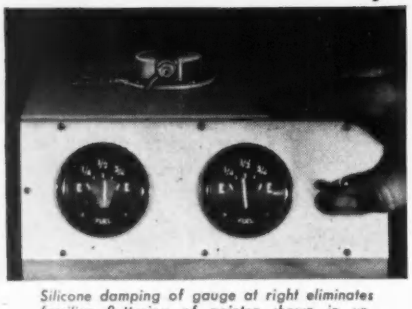

Silicone damping of gauge at right eliminates familiar fluttering of pointer shown in untreated automobile instrument at left.

Design frequently involves a compromise between simplicity of construction and the properties of available materials. New materials are interesting because they generally enable engineers to find more simple and therefore more efficient solutions to design problems. Damping is one of the problems that has been complicated by a lack of stability in fluids.

The instrument division of a large automotive parts manufacturer was not satisfied with the use of inertia wheels, air vanes, or magnetic damping to eliminate the fluttering of instrument pointers. Liquid damping had been considered, but all ordinary light oils or greases thinned excessively when hot or thickened and became useless when cold. More than two years ago, however, their engineers started testing some of our high viscosity silicone fluids.

Extensive road testing has proved that a fraction of a drop of our silicone fluid on the bearings performs better and is more economical than any of the more complicated mechanical damping devices. In tests conducted by aircraft manufacturers where operating conditions for instruments are even more severe, silicone fluid damping was found to be the only entirely successful method. Test performance was so completely satisfactory that the instrument division is now using our DC 200 Silicone Fluid to damp electrical instruments, speedometers, tachometers and gauges.

Among other unique and useful properties are a high degree of stability, a relatively constant viscosity over a very wide temperature range, and good lubricity between certain metal combinations. Our fluids are available in viscosities ranging from 0.65 to more than 250,000 centistokes. For more information phone our nearest branch office or write for catalog No. H 1-16

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Materials Handbook

GEORGE S. BRADY, *materials consultant. Sixth Edition,* 831 *pages,* 5¼ x 8¼ *in. Published by McGraw-Hill Book Co., Inc.,* 330 *W. 42nd St., New York* 18, *N. Y.* $7.

This handbook presents characteristics of many chemicals, combinations, alloys and raw materials. The author has not attempted to give an exhaustive discussion of each material, but indicates its general class and its limitations. Designers, buyers and executives who need specific information on materials can get an idea of the class from this handbook, and actual specifications from material suppliers.

The materials appear in alphabetical order under the name by which they are most commonly called. Other names are included for the material, and the index is set up to show all common names of all the materials mentioned.

Each material is described as to its general physical properties and characteristics. This is followed by a discussion of the quantity of material available, where it is obtained, and how it is produced.

Each of the almost 1,000 materials is mentioned as part of a class of materials and is compared with other members of that group. In doing this, the author brings in many uses for the materials mentioned.

The last 58 pages of this handbook are devoted to tables of physical constants frequently needed for reference. Also included is basic economic data of interest to those dealing in different materials.

Waterbury's Handbook of Engineering

Fourth edition. Revised by: H. W. REDDICK, W. M. LANSFORD, C. O. MACKEY, H. H. HIGBIE *and* H. S. BULL. 386 *pages,* 3 x 5½ *in. Published by John Wiley & Sons, Inc., 440 Fourth Ave., New York* 16, *N. Y.* $2.50.

Completely revised edition of the original handbook by L. A. Waterbury, this book contains sections on many branches of mathematics and the engineering sciences. At the end of the volume are grouped many of the tables needed in ordinary engineering problems.

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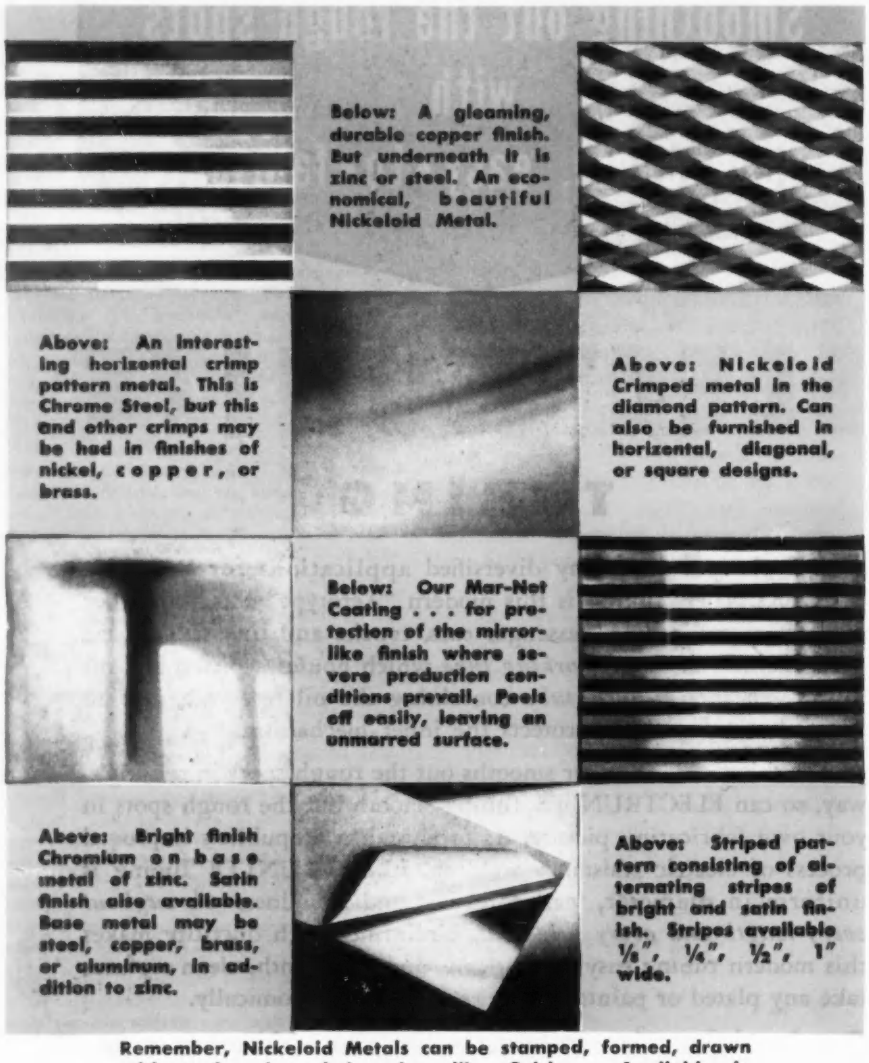

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Standard Welding Symbols

Published by the American Welding Society, 33 W. 39th St., New York 18, N. Y. 69 pages, 5⅞ x 9 in. $.50. (discounts to Society members)

Developed by the Committee on Symbols of the American Welding Society, this booklet gives standard welding symbols and rules for their use. Basic symbols are illustrated in section I. The following sections deal with basic types of joints and welds and general provisions for using symbols. Types of welds allocated to separate sections are: fillet, groove, head, plug, slot, seam, projection and flash and upset welds. The booklet is profusely illustrated with line drawings to illustrate the symbols and their applications to the specific welding process desired. A spread page summary of the standard welding symbols is included in the appendix. A valuable reference for designers, draftsmen, and manufacturing personnel who specify or use welding processes.

Precision Workshop Methods

H. J. DAVIES, *Lecturer in Mechanical Engineering, The University of Sheffield. Second edition revised.* 324 *pages, 5⅜ x 8½ in. Published by Edward Arnold and Co., London, England.* $5.

A well written comprehensive description of the methods used for machining precise work. The test was compiled from notes used in teaching a course in machine shop work for engineering students and thus has a designers point of view. The introductory chapter discusses in detail the need for precision machining and how certain machine details affect the quality of the finished product. Specification of limits and their relationship to manufacturing work is described. In the following chapter limit systems are discussed. Other chapters describe: Machinability, setting out, fixture types, location of work, methods of making fixtures and location of work. Machining methods, indexing, screw threads, special shapes, gear tooth measurement, lapping and grinding, gaging, machines and machine attachments are other chapter headings. An additional chapter on surface finishing has been included in this second edition. Profusely illustrated with

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line drawings, the text includes an appendix giving information for calculating measurement of effective diameter of V-threads and a brief description of the British standard system of limits and fits for engineering. Seven pages of selected references and an alphabetical index are included. This book will be a valuable reference for design engineers, instructors and plant personnel.

The Plating of Zinc Alloy Die-Castings

Zinc Alloy Die Casters Association 132 *pages;* 5 x 7½ *in. Published by Zinc Alloy Die Casters Association, Lincoln House, Turl St., Oxford, England. Seven and six pence.*

Assembled as a symposium covering modern methods of electroplating zinc alloy die-castings, this authoritative book serves as a guide for the expert plater, die caster and consumer. The semi-technical text provides the answers to most of the plating problems commonly met in this field. References noted in the text are listed in a 121-item bibliography. Chapter I deals with the production of castings for plating. Discussions on design, surface finish, inspection, polishing, cleaning and acid dipping are the main topics.

Plating operations are described in Chapter II. Process is traced from the primary deposition of copper or nickel, through the nickel on copper, chromium on nickel, chromium and enamel, or black nickel plating stages to barrel plating with copper and nickel.

Chapter III is devoted to the maintenance of plating baths. Chemical analyses, determination and control of pH, determination of surface tension, and contamination and purification of plating solutions are the subject heads. Determination of coating thicknesses, tests for electrodeposit adhesion and specifications for deposit thicknesses are discussed in Chapter IV.

After a short chapter on stripping plated coatings, there is a detailed flow sheet that lists typical procedures.

Steel Plates and Their Fabrication

408 *pages,* 6⅜ x 9⅜ *in. Published by Lukens Steel Co. and subsidiaries, By-Products Steel Corp. and Lukenweld, Inc.,* 323 *Lukens Bldg., Coatesville, Pa.* $5.

This book contains more than the title implies to the casual reader—it is a comprehensive reference on rolled steel products with much data on their fabrication and application. The designer who deals with plates, shells, weldments, clad steels, spun and pressed heads, pressure vessels and

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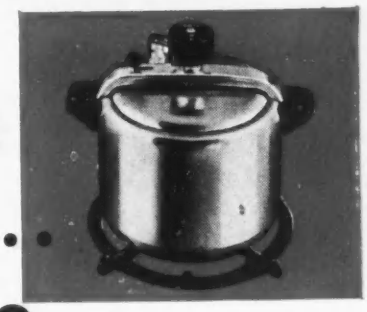

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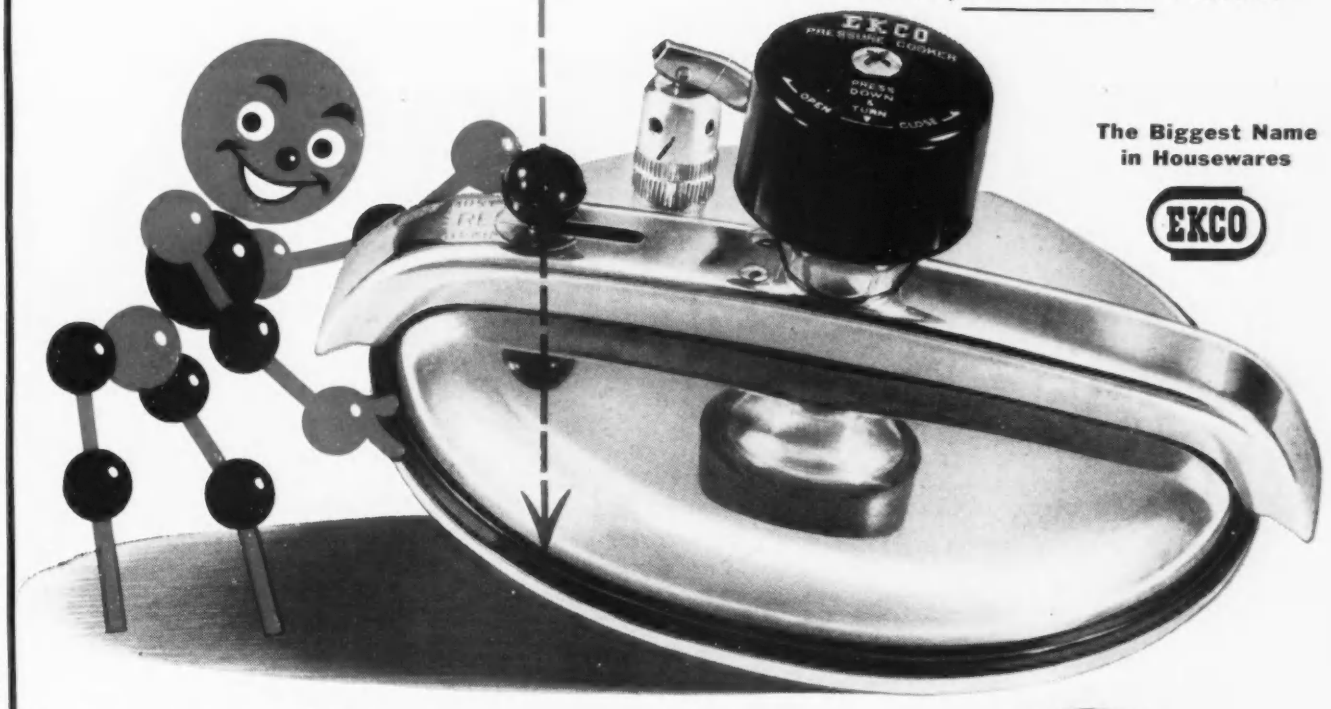
5. *Materially reduced the manufacturing cost of the* EKCO *Pressure Cooker.*



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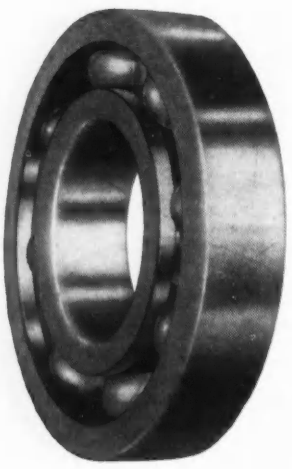

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Steel making procedure is briefly discussed, then on page 31, Chapter V describes "Carbon and Low Alloy Steels", their mechanical properties, methods of working, heat-treatment, classifications, effect of alloying elements, and steels for special purposes. From here to the end, the book is packed with useful data. Chapter VI covers "Effect of Plate Widths on Fabrication Costs". Chapter VII has the theoretical analysis and the ASME code data on the "Strength of Flat Plates and Shells." Forming is described as an introductory chapter to a vast amount of data on flared, flanged, dished, reverse-dished, shallow-dished, conical dished and hemispherical heads.

Flame cutting, welding, riveting are each analyzed. The treatment of clad metals, and fabrication of assemblies from plate components are described in the last two chapters. Ninety-six pages of general engineering data—mathematical tables, trigonometric tables, weights and measures, conversion tables on pressure, velocity, mass, energy, power, heat, density, thermal conductivity, specific gravity, and temperature, mathematical formulas, properties of sections, thread data, and other topics conclude the material.

Industries Answeright

CHARLES Z. SMITH, SR., *President and Chief Engineer, Genaflash Co. First edition, 440 pages, 8½ x 11 in. Published by the Genaflash Co., 105 Grove Ave., Albany 3, N. Y. $6.*

In this book are compiled a large selection of the short-cut methods and computation aids engineers, designers, mechanics and tool designers usually figure out for individual problems. The methods are shown as practical numerical problems, with pictorial representation where possible, and correct solutions, with a minimum of explanation. Derivations of some formulas are shown where fuller explanation is necessary.

Solution of oblique triangles using laws of sine, cosine and tangent are shown in addition to right triangle problems. Comprehensive outlines are arranged for systematically determining dimensions for standard and special thread gages. Also dimensions for several thousand plug and ring thread gages are set up in tables.

One chapter explains compound angle problems as they apply to flat and circular form tools. Another introduces a system for correctly placing the decimal point in slide rule multiplication and division.

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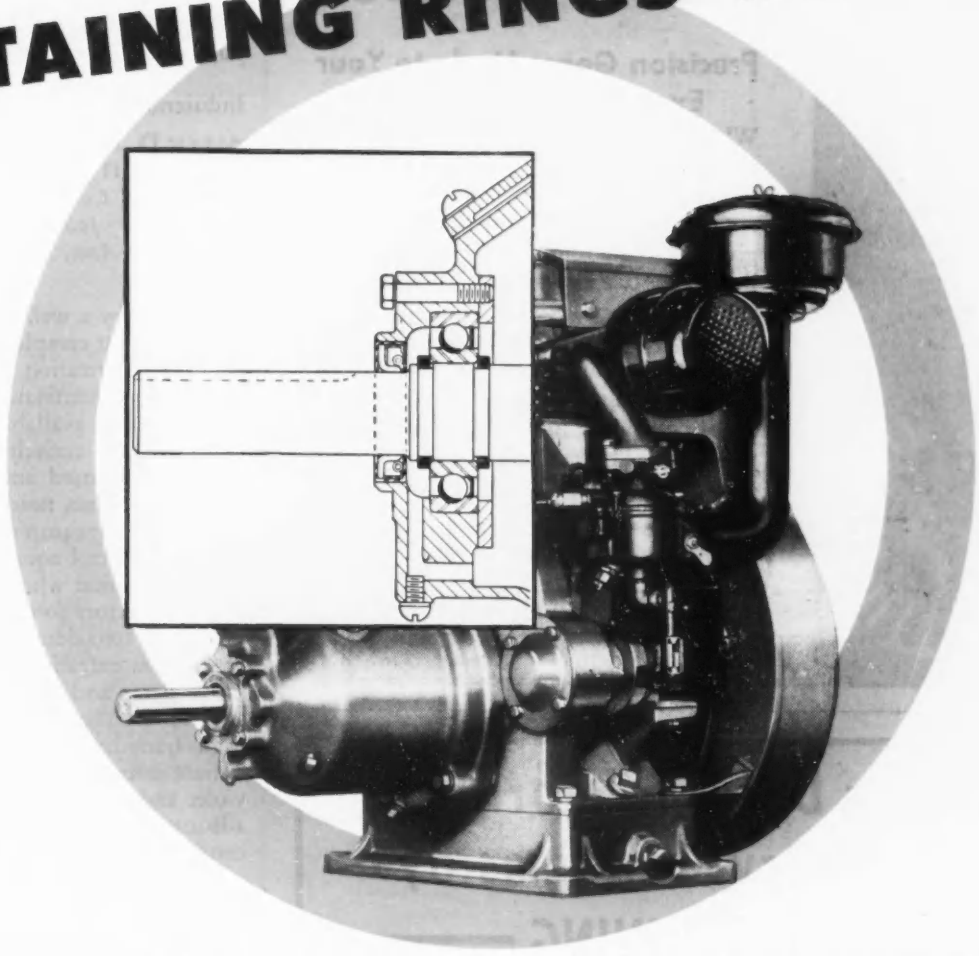

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Industrial Health Engineering

ALLEN D. BRANDT, *B.S., M.S., Sc.D., Industrial Hygiene Engineer, Bethlehem Steel Co.* 395 *pages,* 6 x 9 *in. Published by John Wiley & Sons, Inc.* 440 *Fourth Ave., New York* 16, *N. Y.* $6.

Written by a well-known authority, this is the first complete handbook that presents information on industrial atmospheric contaminants and their control. It makes available to plant engineers and to consulting engineering firms a condensed and practical summary of the data needed to determine what control measures should be taken and how control equipment should be designed so that when installed it will do a satisfactory job.

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Generous use is made of charts, tables and a complete technical appendix thus permitting practical application of the chemical, industrial and mechanical engineering principles involved.

Diary and Sundry Observations Of Thomas A. Edison

Edited by DAGOBERT D. RUNES. 247 *pages* $5\frac{1}{2}$ x $8\frac{3}{4}$ *in. Published by Philosophical Library, Inc.,* 15 *E. 40th St., New York* 16, *N. Y.* $4.75.

Presented for the first time in book form are fragmentary notes and observations from Thomas Edison's diary and speeches. The diary excerpts reflect not only the young mind of the potential inventive genius but also present many interesting historical facts.

The sundry observations that occupy the last two-hundred pages continue the dual character of thought and fact. Often a short autobiographical section, seven chapters take up specific concepts which have a close bearing on the influence of Edison's primary inventions—the incandescent lamp, pho-

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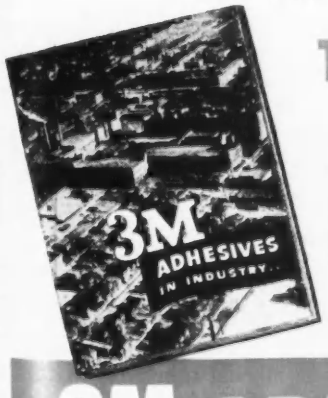

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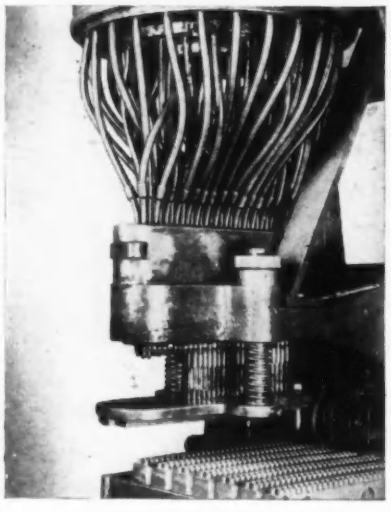

2. **(Left) Flexible shafts give this drill press time-saving, production-boosting versatility by making possible quick regrouping of the spindles to meet a wide range of drilling requirements.**

Product of General Gas Light Co. Kalamazoo, Mich.

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nograph and motion pictures. Chapter heads are: Motion Pictures and the Arts, War and Peace, Education and Work, the Philosophy of Paine, Man and Machine, For a Better World, and The Realms Beyond. Edison's complete philosophy is made quite evident and his predictions of world-wide trends are made the more remarkable by the evolution of events that have already transpired in the few years since Edison's time.

Radiant Heating

RICHARD W. SHOEMAKER, *Consulting Engineer on Radiant Heating and Hydro-Electric Problems, Oakland, Cal.* 306 *pages,* $6\frac{1}{4}$ x $9\frac{1}{4}$ *in. Published by McGraw-Hill Book Co., Inc.,* 330 *W. 42nd St., New York* 18, *N. Y.* $4.

Radiant heating is explained and data is included, not only for the prospective home-builder, but for the architect, contractor, and engineer. Sufficient information is included so that those experienced in conventional heating systems can design a radiant-heating system adequate for the average one-or two-story building. Chapters III and IV cover panel location in the commercial building and the residence. The heating plant, the control system, and the design of radiant heating systems from an empirical viewpoint are then described. A precise method of design, based on the most advanced theories of radiant heat, is covered in Chapter X. Radiant cooling is also described.

Practical Job Evaluation

PHILIP W. JONES, *Director of Industrial Relations, Hilton Hotels Corp.* 304 *pages,* $5\frac{3}{4}$ x $8\frac{1}{2}$ *in. Published by John Wiley & Sons, Inc.,* 440 *Fourth Ave., New York* 16, *N. Y.* $4.

The title fairly describes this excellent book. Emphasis is on the design, installation and salesmanship procedures required to determine the wages of employees in industry and business.

Selection of job characteristics, their weighting, makeup of manuals and questionnaires introduces the reader to the subject. The chapters on the Selection and Evaluation of Key-List Jobs, the Evaluation Process, and Employee Classification tell how to apply the knowledge gained from the questionaires. Development of the Wage Structure and the writing of a Job Evaluation manual conclude the application of the knowledge. The author is careful to emphasize the importance of the way in which job evaluation is introduced to the workers, the union, the foreman, and even management. Much practical advice is included in the next to last chapter, "Selling the Idea of Job Evaluation."

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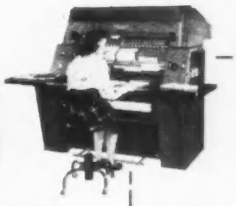

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OUR READERS SAY

Editor's Note: The following are a few of the comments received in response to the special inserts that were published in the March and April issues of PRODUCT ENGINEERING.

Motor Driven Machines

To the Editor:

We find this special insert provided a very good summary of basic motor types and useful information on the application of motors to machines. Each engineer in this Division would benefit from having a personal copy.

—C. M. RHOADES, JR.
Machinery Div., Industrial Engineering Division, General Electric Co.

To the Editor:

I want to congratulate you on the very fine article in the March issue of PRODUCT ENGINEERING. I have turned this over to Mr. Smith who is in charge of our Sales Promotion. The article is so fine that I would like to use it with all our salesmen and possibly a number of our customers.

—P. W. ARNOLD
Motor Applications Engineer, The Reliance Electric & Engineering Co.

To the Editor:

I have just finished reading your insert "Motor Driven Machines" in the March issue. Congratulations on a masterpiece.

My only critical comment concerns the mention of "spiral gears" on page 118. Even though such eminent gear experts as Hall and Buckingham sanction the term, I am "agin it" for two or three reasons. The so-called spiral gears have helical, not spiral, teeth. The use of the word "spiral" to refer to the angularity of the axes is a misnomer. And helical gears on non-parallel axes are limited to light loads. Replacing the word "spiral" by "hypoid" would have been a happy choice.

JESSE HUCKERT, *Secretary*
Robinson Laboratory, USU, Columbus, Ohio

To the Editor:

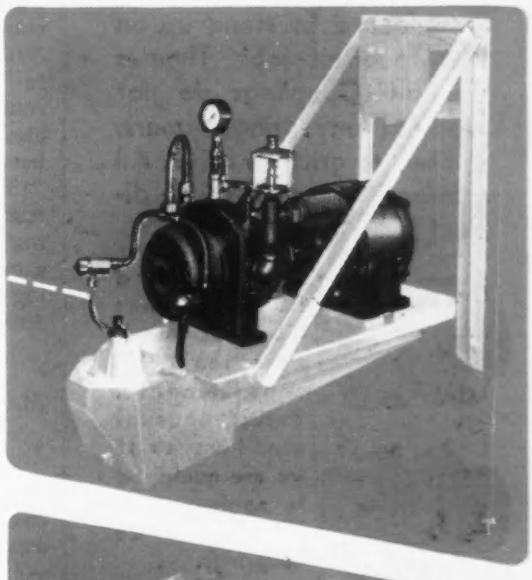
Your article "Motor Driven Machines" is certainly a job well done. I would like to furnish a copy to each

THEY MADE AIR DO THE WORK—

THROUGH *Visioneering* *

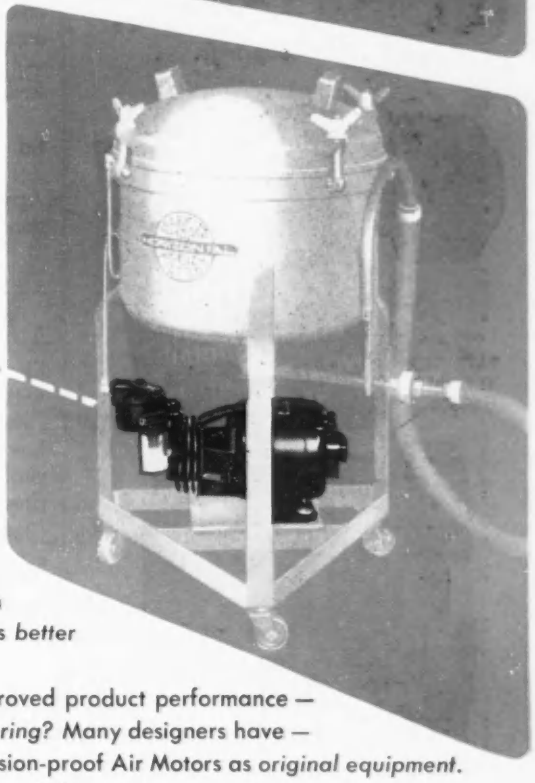
. . . ON A HUMIDITY CONTROL UNIT

Here's Visioneering applied by designers of a Humidity Control Unit for bakery proof-rooms. To atomize water through spray head, a Gast Rotary Compressor, as original equipment, supplies "pulseless" air pressure. No tank needed. Unit keeps air in room at 98% humidity. Direct drive, ¾ H.P. Rating is 8½ C.F.M., pressure to 25 lbs. Compressor has automatic lubricator with visible oil supply, intake filter and cooling fans.



. . . ON A FILTER FOR EDIBLE FAT

On a totally different application, air does the work on another manufacturer's Portable Filter. With pressure to 25 lbs., a Gast Rotary Compressor forces fat through filter medium. This reclaims valuable fat for re-use — effecting big savings. Gast Compressor and motor are integral — only 7" x 12" over-all. Gast's packaged design also speeds manufacturer's final assembly. Rating: 1½ C.F.M. with ¼ H.P.



Both USE GAST ROTARY AIR COMPRESSORS

Notice that the two machines described are *totally unlike*, although both serve in the processing of food. Yet their designers *visioneered* them as *better* products — with Gast Rotary Compressors as original equipment.

Have you a design problem you can solve with AIR? Can you get improved product performance — reduced bulk — increased safety — or better control — through *visioneering*? Many designers have — by specifying Gast *Rotary Design* Compressors, Vacuum Pumps or Explosion-proof Air Motors as *original equipment*.

If *air* pressure, vacuum or power can be applied on your products, we'll be glad to co-operate with engineering help. *For details, write Gast, describing your problem.*

* **Broad vision plus engineering skill.**

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AIR COMPRESSORS — to 30 lbs.
VACUUM PUMPS — to 28 in.
AIR MOTORS — to 1 H.P.

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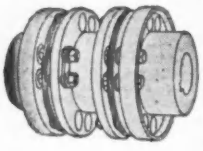
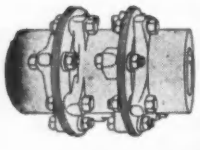
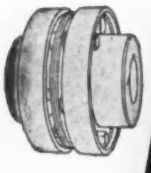


The standard line of Thomas Couplings meets practically all requirements. But if unusual conditions exist we are equipped to engineer and build special couplings.





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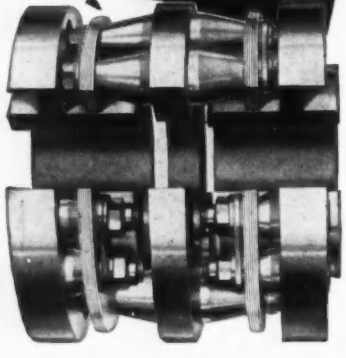

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of our field engineers. Would you be so kind as to send twenty-five reprints.

—VINCENT K. ALEXANDER,
Sales Manager,
Manheim Mfg. and Belting Co.

Experimental Stress Analysis

To the Editor:

My congratulations to you on the publication of your splendid article entitled "Organizing for Experimental Stress Analysis." This paper is going to be most useful to me, not only in connection with my classes here, but also to assist in any talks that I may have to give to professional groups.

The article is so good and I have received so many requests for reprints, that I wonder if I can trouble you for a quotation on reprints in the following quantities: 100, 500, 1000, 2000, 3000 and 5000 copies.

—W. M. MURRAY,
Dept. of Mechanical Engineering,
Massachusetts Institute of Technology

To the Editor:

Sorry to see the credit for Stresscoat illustrations go to Ellis Associates instead of Magnaflux Corporation. —Could that slip on credit be rectified?

—GREER ELLIS,
Magnaflux Corp.

Ed.—It sure could. The pictures under "Fillet Stress Study," p. 119, April issue, came from the files of the Magnaflux Corporation.

To the Editor:

The best compliment I can pay you is that I wish I had written something like this myself. I have been boiling with enthusiasm over your complete coverage of the subject, the simplicity, brevity, the definite statement of a problem and its equally definite solution; the clear, schematic diagrams and illustrations and the sustained interest throughout.

I have been trying to write in *News Letters* and *Testing Topics* in an effort to simplify a complex subject for these many years. You ought to get a tremendous response from this article. It is way ahead of your Stresscoat compilation (PRODUCT ENGINEERING, December 1946 Page 122.)

—F. G. TATNALL,
Sales Engineer, Strain Gage Dept.,
Baldwin Locomotive Works

To the Editor:

Congratulations on your latest Experimental Stress Analysis presentation. We have been hearing about this work in progress by you, but I am still pleasantly surprised at the full coverage and contents you have managed to get into this presentation. I

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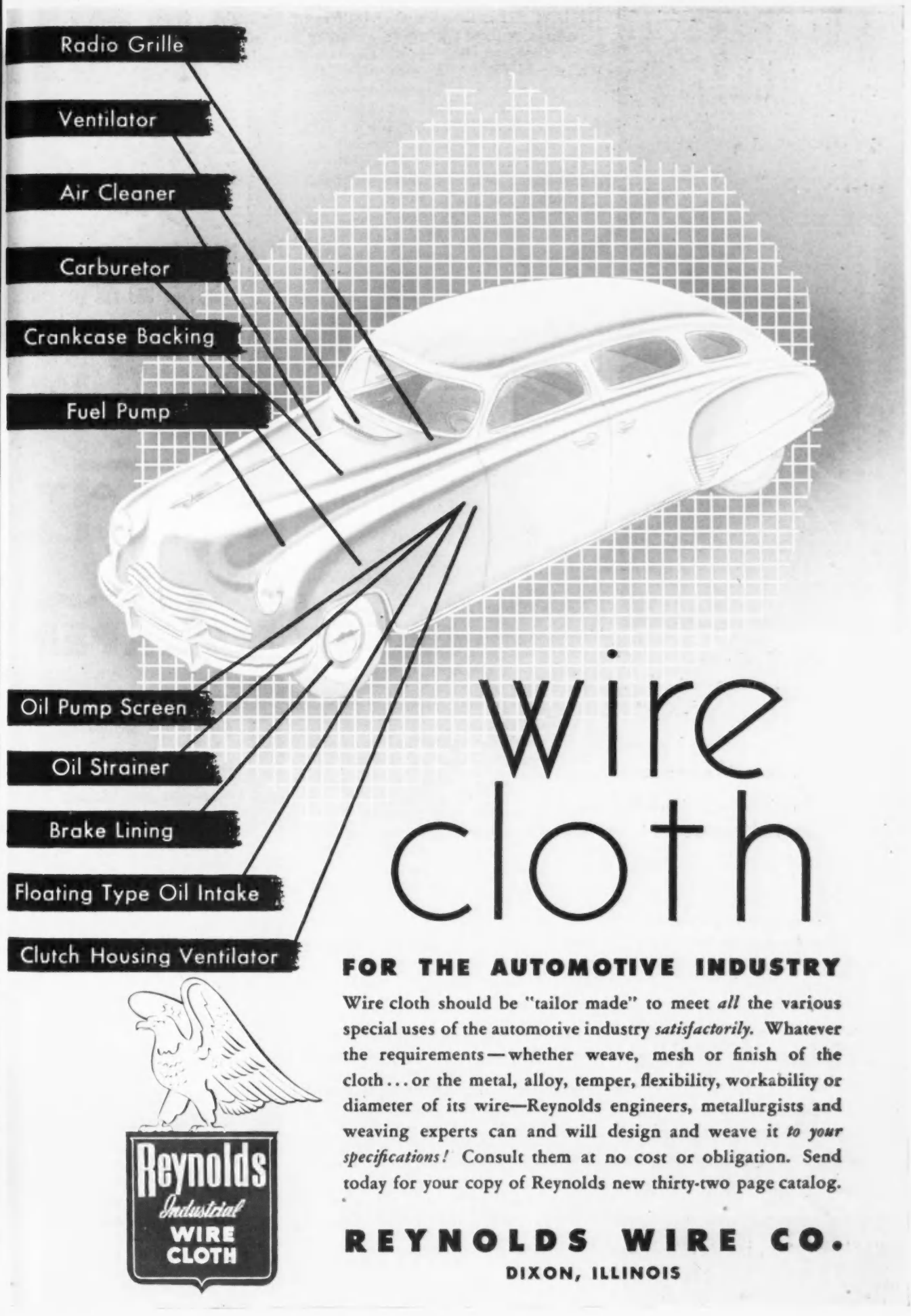

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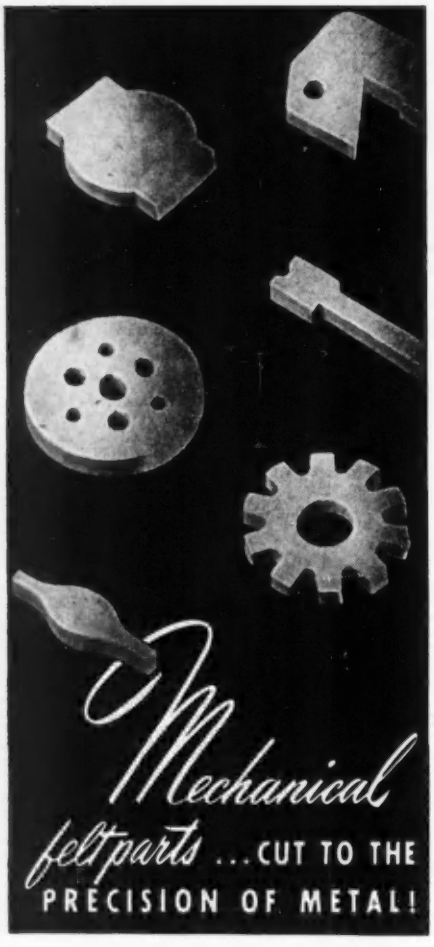

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believe that is the clearest overall exposition of these techniques, including our Stresscoat, that has appeared.

Would you be kind enough to advise me what the cost is for these booklet reprints? I should like to know the cost in lots of 500 and of 1000.

These reprints should certainly be of value in furthering the usefulness of Experimental Stress Analysis as the powerful tool that it can be.

—FRANKLIN S. CATLIN,
Technical Coordinator,
Magnaflux Corp.

To the Editor:

We have read your very well done article on Experimental Stress Analysis in the Aril issue of PRODUCT ENGINEERING, and wish to compliment you on a fine job.

Quite often people come to this office to get some information on stress analysis. Many of them are not too well posted. It would be very helpful to us, if we could show them your article and give them a copy of it. Would it be possible for us to obtain about 30 to 40 reprints?

—J. H. MEIER,
Research Engineer,
Bucyrus-Erie Co.

To the Editor:

I was greatly interested in your excellent survey on "Experimental Stress Analysis" in the April 1948 PRODUCT ENGINEERING.

Each fall I give a graduate course entitled "Research Methods" which is taken both by mechanical and civil engineering students at Lehigh. It would be of great value to the class if I could distribute a reprint copy of your survey to each member. Fifty copies would be enough to last me three years by which time your survey would probably be repeated.

—BRUCE G. JOHNSTON,
Director,
Fritz Engineering Laboratory,
Lehigh University

Spring Formula

To the Editor:

I would like to call your attention to a typographical error in the article "Formulas for Spring Redesign" by A. Bodenschatz, on page 143 of the April PRODUCT ENGINEERING.

In the first column, just below the list of symbols, you have the equation

$$K = \frac{GD^4}{8ND^3}$$

which should be

$$K = \frac{Gd_w^4}{8ND^3}$$

as per standard texts. The next equation proves this, since it is correct and is derived from the preceding equa-

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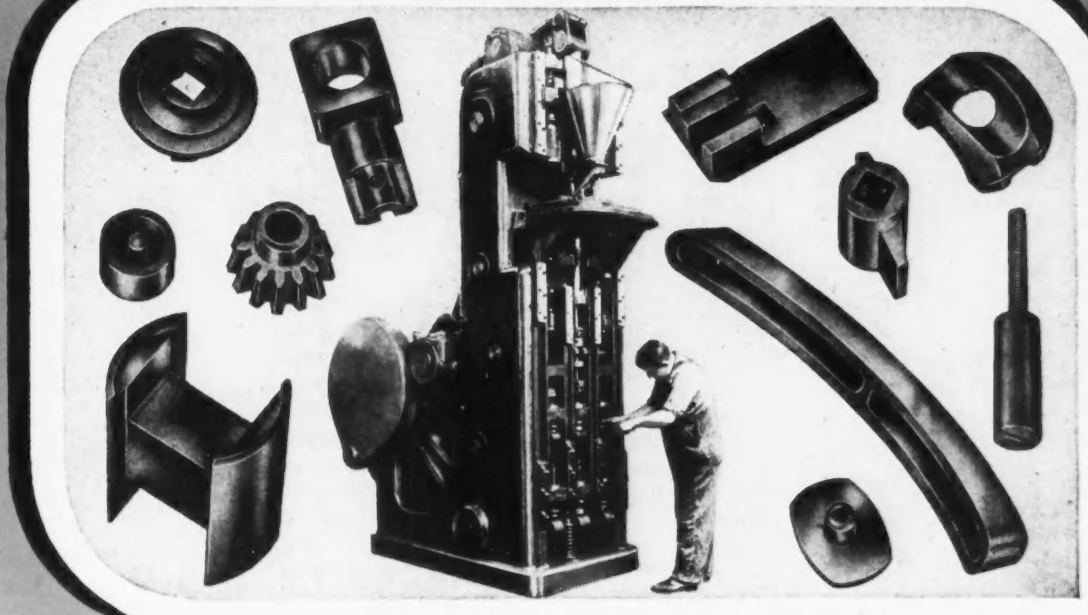

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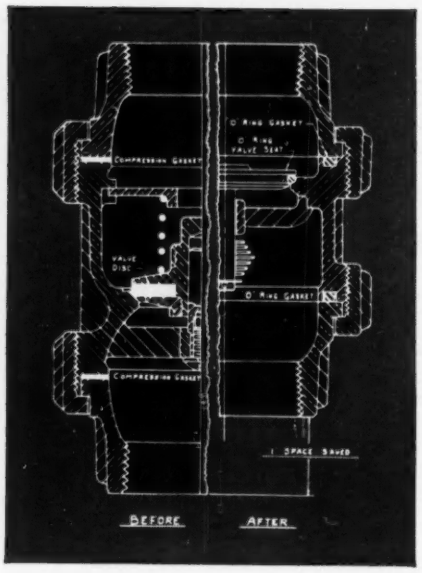
Look at the improved design made possible by using "O" Ring Seals in this double union vertical check valve made by THE OPW CORPORATION of Cincinnati, Ohio—for gasoline, benzol, fuel oil and other fluids.

Compression gaskets and a synthetic rubber valve disc were used in the original design shown at the left. By using "O" Rings the unions are screwed down only finger tight to prevent leakage. An "O" Ring is stretched over the valve disc to make a tight seal under all conditions. These changes shortened the valve 1 inch, eliminated several parts, simplified the others, reduced costs and weight, and improved the flow characteristics.

This is an example of how your problem could be solved by using "O" Ring designs. For complete Engineering Data write for our "O" RING HANDBOOK.



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tion by substituting H/d_w for N in the denominator.

—COUNT HARVEY
Mechanical Engineer,
U. S. Bureau of Reclamation,
Denver, Colo.

Ed.—We accede to Mr. Harvey and the texts.

Industrial Design Courses

To the Editor:

The correspondence on Industrial Design Courses as published in the Our Readers Say columns of the March PRODUCT ENGINEERING prompted me to acquaint you with the educational activities of the American Designers' Institute.

This organization, the oldest of its kind in this country, has a very active Committee on Education. This group has planned a four year curriculum leading to a degree in Industrial Design and a number of schools are using it as a guide. The following schools are recommended by the Committee for training in this field:

Brooklyn Technical High School, Brooklyn, New York
California Graduate School, C.I.T., Pasadena, Calif.
Carnegie Institute of Technology, Pittsburgh, Pa.
Chicago Art Institute, Chicago, Ill.
Cooper Union, Cooper Square, New York, N. Y.
High School of Industrial Art, 211 East 79th St., New York
Pratt Institute, Brooklyn, New York
Rhode Island School of Design, Providence, R. I.
Syracuse University, Syracuse, New York
University of Cincinnati, Cincinnati, Ohio
Yale University, New Haven, Conn.

—CHARLES DAVIES, *Secretary,*
New York Chapter,
American Designers' Institute.

Ed.—Industry will profit by the work of the Institute's Committee on Education.

Rotary Pump

To the Editor:

We noted with interest the description of the Sundberg Rotary Pump on page 118 of the February PRODUCT ENGINEERING. Will you please advise the address of the Paul Engineering Company so that we may secure all available information on discharge rates, pressures, speeds and price of the smallest capacity Sundberg Pump?

—H. B. ADAMS, *Buyer,*
Frigidaire Div., General Motors Corp.

Ed.—Send your inquiries to Paul Engineering Co., Detroit 12, Mich.